DOCUMENT RESUME

ED 246 582 EC 162 775

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TITLE Comparison of Apple, Epson, IBM, and Other Microcomputers for Applications in Rehabilitation Systems for Persons with Physical Handicaps. Revision D.
INSTITUTION Wisconsin Univ., Madison. Trace Center.
PUB DATE Feb 84
NOTE 95p.
AVAILABLE FROM Trace R and D Center, 314 Waisman Center, 1500 Highland Ave., Madison, WI 53706 ($8.50 plus shipping).
PUB TYPE Reports - Descriptive (141) -- Guides - Non-Classroom Use (055)

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS Computer Software; Elementary Secondary Education; *Microcomputers; *Physical Disabilities; Rehabilitation

ABSTRACT

The paper analyzes major microcomputer systems and their use in rehabilitative systems for persons with physical handicaps. Four categories of microcomputers are addressed: systems designed for home or school with emphasis on low cost, recreation, and educational software; general purpose microcomputers with applications in a large number of areas; systems primarily designed for business and professional applications; and hand-held or fully portable microcomputers. Characteristics of microcomputers as they relate to rehabilitation applications are described. Profiles are then presented by feature (such as size, weight, tape, input speed, cassette power control, disk capacity, memory, display), by weight and size, execution (bench mark tests), and cost. A review of desired characteristics in terms of input, feedback, ability to meet needs, and purchase and maintenance follows. Thirteen individual computers are then summarized and pictured. The report concludes with general guidelines for selection of computers. (CL)

COMPARISON OF APPLE, EPSON, IBM,... MICROCOMPUTERS FOR APPLICATIONS IN REHABILITATION SYSTEMS FOR PERSONS WITH PHYSICAL HANDICAPS

(REVISION D)

February 1984

Trace Center

Trace Research and Development Center
For the Severely Communicatively Handicapped
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COMPARING THE APPLE, EPSON, IBM AND OTHER MICROCOMPUTERS FOR APPLICATIONS IN REHABILITATION SYSTEMS FOR PERSONS WITH PHYSICAL HANDICAPS

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This report is an active report, and is therefore in the process of continual expansion and revision . Please feel free to mark up, question, or add to the contents of it at any time. Send your corrections or comments on a separate piece of paper. (A revised copy of the report will be sent to anyone providing extensive revisions or corrections.)

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PREFACE

The purpose of this document is to provide comparative profiles of major microcomputer systems and their utilization in rehabilitative systems for persons with physical handicaps.

The research leading to this document was done in order to select the best computer for use in a semi-broad range of applications in the above-named areas. It was the objective of this project to identify the computer which would be the best fit for these applications and/or the computer which would be most widely used. Ideally, one computer will be used, thus facilitating the sharing of software, hardware modification and accessories between research and rehabilitation groups and facilitating/accelerating the advancements in this area and the availability of effective systems to people who need them.

ACKNOWLEDGEMENTS

Appreciation is expressed to Craig Heckathorne, whose efforts convinced us of the necessity for such a study before selecting a computer for our work, and also to the following individuals who assisted us in the preparation of aspects of this work.

Jim Armstrong	Blue Lakes Computers - Madison
Michael Dhuey	Independent Consultant (Apple)
Per Krogh Hansen	Polhemus Navigation System
Craig W. Heckathorne	Northwestern University, Rehabilitation Engineering Program
Michael Heckman	Blue Lakes Computers - Madison
Robert Mroz	Federal Communications Commission
Allen Oppenheimer	Apple Computer, Inc. - California
Jim Rae	Independent Consultant - TRS-80
Jim Sullivan	Computerland - Madison
Quentin Verdier	Radio Shack - Madison

INTRODUCTION

INTRODUCTION

The purpose of this report is to provide comparative profiles of major microcomputer systems and their utilization in rehabilitative systems for persons with disabilities.

In general, microcomputers can be broken down into several categories according to their capabilities, price, and the areas of application for which they are suited. This categorization is helpful in isolating features and comparing microcomputers for application with a specific client for a specific application. It is also somewhat arbitrary, since one computer may be placed in several categories depending on which features are emphasized. Four categories are used in this report. These are:

Type 1: Systems designed primarily for home or school with emphasis on low cost, recreation and educational software.

Type 2: General purpose microcomputers that have applications in a large number of areas, are expandible to rival large systems, and have many options available in both hardware and software.

Type 3: Systems that are primarily designed for business and "professional" applications as evidenced by their cost and the types of software available.

Type 4: Hand-held or fully portable microcomputers, whose size, weight, and battery operation make them suitable for applications in which the user must move freely from place to place.

This report includes more than 15 microcomputers selected on the basis of their suitability to the solutions of problems commonly faced by persons with disabilities. These systems include:

Type 1: Atari 400, Radio Shack Color Computer, Vic 20, Sinclair Spectrum

Type 2: Apple II Plus, Atari 800, PET, TRS-80 Model III, Commodore 64, Apple IIe

Type 3: Apple II and III, CBM, IBM Personal Computer, TRS-80 Model II, Xerox 820, Macintosh

Type 4: Epson HX-20, Sharp PC-1500/Radio Shack PC-2, Teleram 3000, Panasonic/Quasar HHC, HP 75, Teleram 3000

Types 1, 2, and 4 are most likely to be procured for a single disabled client. Types 1 or 2 are the most likely to be acquired by school districts and colleges. Type 3 is mostly used in business or other vocational applications.

These potential uses are by no means restrictive, and any one computer may be used in any specific application. Many applications are much less dependent on the type of computer than they are on other factors such as the familiarity of the person making the recommendation with the capabilities of any one system.

MICROCOMPUTER CHARACTERISTICS

AS THEY RELATE TO REHABILITATION APPLICATIONS

MICROCOMPUTER CHARACTERISTICS

AS THEY RELATE TO REHABILITATION APPLICATIONS

In this section we describe characteristics of microcomputers that are potentially useful to persons with disabilities. Because there are so many different characteristics of microcomputers, an analysis of all of them is both confusing and overwhelming. Fortunately, not all characteristics are equally important and many characteristics are possessed by all microcomputers and therefore do not form the basis for any comparison among types. The characteristics discussed in this section are the ones that we have identified as important to the use of microcomputers in rehabilitation. The choice of characteristics will also provide the basis for comparison once a specific type of problem for which a microcomputer might be used has been identified. The characteristics discussed in this section are divided into three categories:

1) Characteristics which affect the user's ability to operate the aid

2) Characteristics which affect the ability of the aid to meet the individual's needs

3) Characteristics affecting purchase, maintenance, etc.

Not all of these characteristics are important in any given situation or for any given person. Some of the characteristics listed below are, in fact, incompatible with other characteristics. For example, a system with a very large display may be necessary for someone who has a visual impairment, but may be of little or no value as a portable writing system for an ambulatory but physically handicapped individual. The ideal system for a given application would be the system which meets the greatest number of important constraints or features for that particular application. As a result, of course, there is no one overall "best" microcomputer.

Below is a discussion of each of the different aspects of a microcomputer which you might want to consider based upon specific applications. Later, after each of the various systems has been profiled, there is a second discussion of these various aspects as they relate to specific applications, including case examples of how one might compare and contrast aids.

CHARACTERISTICS WHICH AFFECT THE USER'S ABILITY TO OPERATE THE AID

INPUTS

KEYBOARDS

A Separable Keyboard: can be helpful when special keyboards or modification to keyboards are necessary. It allows for a more simple and straight-forward servicing of the computer as well as a less severe investment when physical keyboard modifications are necessary. A physical keyboard can also be important to allow precise positioning of the keyboard for better access by motor-impaired clients.

Feedback From Keys: is important for many individuals' use of the keyboards. Membrane keyboards lack tactile feedback, but are often sealed against dirt and moisture. Keyboards of this type should provide some type of 'click' or 'beep' feedback to the user. Mechanical switches (such as on a standard typewriter) provide better tactile feedback.

Size Of The Keyboard: can significantly effect the individual's ability to use the keyboard. Originally, it was thought that the larger the keyboard, the easier it was to use. Clinical results, however, have shown that many more involved individuals do much better on a smaller keyboard where they do not have to reposition their hand between keystrokes.

Shift/Lock Keys: Shift/lock is useful, but of only limited value if there is not also a "control" key lock (which no computer currently has). If a special modification is needed for the Control key it can just as easily be provided for the Shift key at the same time.

Keyguard Availability: can be important to access of the computer by certain physically handicapped individuals. These keyguards are usually specific to the computer. Although custom keyguards can be made, it is usually much easier to see if a prefabricated keyguard exists for the computer in question. Many prefabricated keyguards also have shift/control key 'hold down' mechanisms enabling one finger (or headstick) typing.

Keyboard Emulators Availability: is important if the individual is unable to use the standard keyboard and the user wants to be able to use all of the standard software for a computer. (See Appendix A.)

SWITCH INPUTS

If your application requires special input switches, then you should check for game switch inputs on the computer. These may often be provided in conjunction with paddles or a joystick. If a computer does not provide for any games with inputs, a parallel input port can sometimes be used with minor modification.

ANALOG INPUT

Some applications require the use of joysticks, game paddles, or analog input signals. If these are needed, it is very important that the computer have some provision for game paddle or joystick input. If it does not, it can be quite complicated to interface them to the computer.

LIGHTPEN

Recent advances in using special long-range lightpens as headpointers has made this feature more valuable than previously. The very recent development of a long-range lightpen which can connect to a standard serial port, however, makes special lightpen inputs to the computer a useful, but not critical feature.

FEEDBACK CHARACTERISTICS

DISPLAY

Character Size:: can affect the person's ability to see the display. The size of the characters, however, is often at odds with the number of characters on the display and the overall size of the display. The number of characters on the display relates to the usefulness of the display (see below) and the overall size of the display can affect the portability of the system. For computers that use standard televisions, or television monitors, as their output displays, it is possible to make the characters larger by simply using a larger monitor or televison set.

Active vs Passive Lighting Display: A very common, low power display is the liquid crystal display. These passive displays are, however, somewhat more difficult to see than the active CRT-type display where the characters are actually luminous. The visibility, or readability of the display is also greatly affected by the solidness of the characters. For individuals who are having visual problems, a high resolution display which does not break up the characters into dots as visibly may be easier to distinguish. (It should also be noted that LCD displays cannot be read with an Opticon.)

Upper/Lower Case Capability: For young individuals whose education materials are in primary or lower case, a system which displays its output in the same form (e.g.,lower case) may be easier to learn and use within a standard curriculum. (See also "Output - Displays" below.)

AUDIO FEEDBACK

'Click' Feedback: can be very useful for individuals who have poor tactile or kinesthetic feedback to provide confirmation of switch activation.

Speech Feedback: is available for any computer with an RS-232 interface. Medium quality text to speech synthesizers are available as free-standing units which can connect to any computer with an RS-232 interface. In most cases, the speech feedback only works with software which has been specifically written to provide speech feedback. It can be very useful for reinforcement to youngsters and individuals just learning to read and spell. It can also be useful to individuals with visual impairments, although special hardware or software designed specifically for blind individuals is usually required if one intends to use it with standard software (see Appendix A).

CHARACTERISTICS AFFECTING THE ABILITY OF THE COMPUTER TO MEET THE INDIVIDUAL'S NEEDS

OUTPUTS

CORRECTABLE DISPLAYS

Correctability: is essential for most tasks. Some type of visible, correctable display is generally needed both by young individuals to allow them to learn and correct mistakes and by older individuals to allow them to complete and submit quality work for education or employment.

Number Of Characters Per Line: Most writing tasks are easiest with an 80-character line. This also enables users to see what the format would be like when it is printed on regular size paper. Large displays can be difficult, however, in portable instruments. A smaller number of characters may also be helpful for persons with visual impairments, since a larger character size can be used. 20 to 40 characters is usually generally sufficient for communication purposes. Less than 16 is of little value for communication.

Number Of Lines Of Text On Display - 64 lines would be needed to display a full page of text. Most computers display 16 or 24 lines on the screen at one time. Single line liquid crystal displays make editing of text or programs very difficult and make mathematical manipulations for instruction impossible. (For instance, try to teach addition of 4-column math with the numbers lined up side-by-side.) A 4-line liquid crystal display makes simple mathematical formatting possible. They are also useful for simple text editing. Serious text editing or writing systems should look toward larger displays.

Upper/Lower Case Capability: makes reading the display much easier. Upper/lower case display is usually necessary for business and word processing applications and, as mentioned above, can be important if the application is with young readers and language learners.

High Resolution Graphics/Color: is generally important only if there is a specific need for it by the client (as high resolution graphics are for Blissymbol displays). Normal graphics are generally sufficient for business and educational graphing and plotting.

PRINTED OUTPUT

Thermal vs Impact vs Ballpoint Pen Printers: The thermal-type printers are generally cheaper, but the paper is more expensive. Thermal paper fades with time or when tape or glue is placed in contact with the characters. Thermal printers, however, are quite quiet, and may be the printer of choice in applications with individuals having high startle reflexes, or in environments where other printers would be disruptive.

Impact printers vary widely in quality and price, and can be divided into two categories; a) letter quality printers, and b) dot matrix printers. Letter quality printers (typewriter style) are generally more expensive and cannot usually print graphics. Dot matrix printers can be quite inexpensive and allow for graphics. They can also be much smaller in size than the letter quality printers.

More recently there have emerged ballpoint pen printers which actually draw the characters. These have the advantage of being able to draw solid characters in various sizes. They generally also are able to draw them in multiple colors if this is needed. Ballpoint pen printers are only moderately noisy.

Speed: can be an important factor if the works being printed are are of any length. Slow printers can take long periods of time to print completed documents. This is a problem whether the text was entered rapidly (e.g. a blind typist) or slowly (e.g. a motor-impaired typist). Slow, low-cost printers, however, may have many applications where the individuals using them will not be printing out large quantities, especially with very young individuals who are using them as initial writing aids.

Paper Width: Printout that is less than 16 columns wide is not of much use for text printout. Printouts less than 8 1/2" wide, however, can be both convenient and effective. Continuous roll, or continuous fold sheet printers, can be very helpful in that they reduce the amount of paper manipulation necessary. Perforated paper (either folded or roll) is preferred since it is much more easily separated into individual sheets.

Graphics Printing Capability: would, of course, be necessary whenever graphics are required (e.g. Blissymbols). They can, however, also allow for the printing of enlarged characters for individuals with vision impairments.

Most printers will work with any computer, so this does not generally affect the choice of computer. The exception to this would be small portable computers where the printers are actually built into the unit.

OTHER OUTPUT FORMS

RS-232 Output: is almost always recommended or required. This is a standard interface port and can be used with printers, voice synthesizers and a wide variety of other accessories.

Phone Modems: can be used to allow the individual to connect his computer over phone lines to 'talk' to other computers or information systems.

Other Items: Manipulators (robotic arms), environmental control systems, powered mobility controllers, etc., can also be hooked to the computers. In some cases, they are designed specifically for computers. Other forms, however, operate off of RS-232 ports and can therefore be used with any computer having an RS-232 port.

PROCESSING AND STORAGE

STORAGE

Disk Drives: are recommended for any serious use of the microcomputer which involves storage of information. Disks are easier to manipulate than cassettes and allow much more automated control by the computer. They also store more and are much faster. New 3" cassettes come in sturdy plastic cartridges (versus the more flexible and fragile floppy disks) which can be handled fairly much with impunity by motion impaired individuals. The 3" disks are now becoming available for most computers.

CMOS RAM: a special type of low power memory (CMOS RAM) is provided in many newer and portable computers. This allows the computer to retain the program in memory even when it is turned off. This in turn allows the individual to keep a program in his computer between uses and can reduce the need for disk drives or other storage mediums, especially with portable aids.

Computer Memory Size: The computer memory is generally measured in 'K', which stands for approximately 1000 bytes of memory (1,024 to be exact). A 16K memory, therefore, would

have approximately 16,000 bytes of memory. 10-16K is generally the minimum for a meaningful program. 48K, or more, is desirable for most education and business applications.

TRANSPORTABILITY

A key factor in evaluating the computers is whether or not they will be available to the individual when he needs them. Systems which are non-portable should be thought of as work stations. Communication aids clearly would have to be very portable systems. Writing systems for handicapped individuals would also have to be quite portable, in the same way as pen and paper must be for education and/or employment. Some individuals may be using their computer for multiple applications, some of which are mobile and some of which are a work station. In these cases, they may use a computer which has the necessary capabilities in a portable form, but which can be expanded in a work station form to provide additional capabilities. Systems which are expected to be carried about should also be one integral piece. Individuals who must carry a small system around as a writing system, for example, should not have to stop and unpack or assemble it each time they want to use it.

AVAILABILITY OF DESIRED MODIFICATIONS/ACCESSORIES

Ability To Customize: The system should allow for ease in modification to meet specific needs. Systems which have modular slots or are designed to accept accessories are generally better suited to rehabilitation applications than units which are sealed and do not provide any expansion slots, etc.

CHARACTERISTICS AFFECTING PURCHASE, MAINTENANCE, ETC.

Modularity: Systems which are modular allow the individual to purchase only what is needed now and expand the system as his needs and/or resources grow. Modular systems also can ease in transportation where the entire system is not required. In some cases, large parts (e.g., a tv display) can be duplicated in two locations so that the individual need not transport that portion. Maintenance is also simplified if individual modules can be removed for maintenance.

Wide Distribution/Repair Networks: The more commonly available the aid or system is, the more likely that repair services will be available. If you are in a large city, this may be less of a concern, since there may be repair for most any system. In rural communities, however, it may be a significant consideration.

COMPARATIVE PROFILES

The following pages are provided for you to profile the various computers you are interested in. In order to get an idea of some of the things you may want to watch for or note, we have included examples of several commonly used computers.

Blank columns are provided on each of the profile pages to allow you to compare other computers.

COMPARISON BY FEATURE

FEATURES

	TRS-80 MODEL III		COMMODORE 64		APPLE II
SIZE (inches) H x W x D	3.5 x 13.75 x 14.75		3 x 16 x 8		4.5 x 15.25 x 18.0
WEIGHT (pounds)	10.0				11.5
TAPE INPUT SPEED	1500 Baud		300 Baud		
CASSETTE POWER CONTROL	YES		YES		NO
CLOCK	2.03 MHz		1.0 MHz		1.0 MHz
CPU	Z-80		6510		6502
CPU-RAM	48K		64K		64K
RAM AVAIL. (After Basic & DOS Loaded)			64K (Basic in ROM)		52K
DISK CAPACITY	175K		170K		140K
POWER DISTRIBUTION	Internal Power Supply		Wall Transformer		Internal Power Supply
DISPLAY	Built-In HiRes 12" B&W Monitor		Monitor Extra		Monitor Extra
" "	64 Graphics Characters		16 Color Graphics 320 x 200 Pixels (Hi-Res)		LoRes: 16 Clrs 40 x 48 Blocks HiRes: 6 Clrs 280 x 192 Pixels
" "	32/64 Chr/line 16 lines		40 Char/line 25 lines		40 Char/line 24 lines
" "	Upper/Lower Case		Upper/Lower Case		Upper Case Only

FEATURES

	APPLE IIe		IBM PERSONAL COMPUTER (WITH COLOR BD)		SHARP 1500/ RADIO SHACK PC2
SIZE (inches) H x W x D	4.5 x 15.13 x 18.16		15.5 x 20.0 x 16.0		10.04 x 7.67 x 3.386
WEIGHT (pounds)	12.0		21.0		0.827
TAPE INPUT SPEED			---		
CASSETTE POWER CONTROL	NO		YES		YES - 2
CLOCK	1.0 MHz		4.77 MHz		
CPU	6502A		8088		
CPU-RAM	64K		700+K		3.5K-11.5K
RAM AVAIL. (After Basic & DOS Loaded)	64K (Basic in ROM)				
DISK CAPACITY	143K		320K		
POWER DISTRIBUTION	Internal Power Supply		Internal Power Supply		Battery & Wall Charger
DISPLAY	Green Phosphor Monitor Included		Color Monitor Extra (IBM Monochr avail)		LCD
" "	LoRes: 16 Clrs 40 x 48 Blocks HiRes: 4 Clrs 280 x 192 Pixels		B&W Graphics: 640 x 200 Pxs; 16-Clr Graphcs 320 x 200 Pxs, w/Graphcs Brd.		
" "	80/40 Chr/line 24 lines		80 Char/line 25 lines		Upper/Lower Case
" "	Upper/Lower Case		Upper/Lower Case		

FEATURES

	PANASONIC/ QUASAR HHC		EPSON HX-20		HP 75C
SIZE (inches) H x W x D	1.1875 x 8.9375 x 3.75		1.75 x 11.375 x 8.5		1.25 x 10.0 x 5.0
WEIGHT (pounds)	1.25		3.8125		1.625
TAPE INPUT SPEED					
CASSETTE POWER CONTROL			YES		
CLOCK	1.0 MHz		0.614 MHz		
CPU	6502		Two 6301's		Z-80
CPU-RAM			16K-32K		16K-28K
RAM AVAIL. (After Basic & DOS Loaded)					
DISK CAPACITY	---		320K		
POWER DISTRIBUTION	Battery & Wall Charger		Battery & Wall Charger		Battery & Wall Charger
DISPLAY	LCD and TV (optional)		LCD and TV (optional)		LCD and TV (optional)
" "	8-Color Grphcs Range From 64 x 32, 64 x 48		Bit Address Graphics; 120 x 32 Dot Matrix		
" "	32 Char/line 1 line		20 Char/line 4 lines		32 Char/line 1 line
" "	Upper/Lower Case		Upper/Lower Case		Upper/Lower Case
" "					

FEATURES

	TRS-80 MODEL 100				
SIZE (inches) H x W x D	11.625 x 8.25 x 2.0				
WEIGHT (pounds)	3.875				
TAPE INPUT SPEED					
CASSETTE POWER CONTROL	NO				
CLOCK	2.4 MHz				
CPU	80C85				
CPU-RAM	8K-32K				
RAM AVAIL. (After Basic & DOS Loaded)	5.1K-29.6K				
DISK CAPACITY	---				
POWER DISTRIBUTION	Battery				
DISPLAY	LCD				
" "	128 character graphics 240 x 64 Pixels				
" "	40 Char/line 8 lines				
" "	Upper/Lower Case				
" "					

COMPARISON BY WEIGHT/SIZE

WEIGHT/SIZE

	TRS-80 MODEL III		COMMODORE 64		APPLE II
CPU (size = in. H x W x D)	(Display Unit)		3 x 16 x 8		11.5 lbs. 4.5 x 15.25 x 18.0
TAPE	10 lbs. 3.5 x 13.75 x 14.75		C2N Datasette 3.0 x 6.5 x 8.0		---
TV DISPLAY	12.5 x 18.875 x 21.5		Any TV Monitor		Any TV Monitor
EXPANSION	---		---		---
MODEM	Acoustic Modem 2.375 x 4.75 x 10.25 x 10.25				Plug-In Card Card
DISK DRIVE - SMALL	7.0 lbs. 6.25 x 3.5 x 14.5		(1540) 5.0 lbs.		Apple Disk II 3.0 lbs. 3.25 x 5.75 x 8.0
THERMAL PRINTER	---		---		6.0 lbs. 2.75 x 7.75 x 12.25
IMPACT PRINTER	LinePrntr VIII 16.5 lbs. 4.7 x 15.4 x 11.0		9.0 lbs. 5.0 x 8.0 15.0		---
KEYBOARD (if Separate)	---		---		---

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WEIGHT/SIZE

	APPLE IIe		IBM PERSONAL COMPUTER (WITH COLOR BD)		SHARP PC1500/ RADIO SHACK PC2
CPU (size = in. H x W x D)	12 lbs. 4.5 x 15.13 x 18.16		21.0 lbs. (w/o disks) 5.5 x 20.0 x 16.0		10.04 X 7.67 x 3.386
TAPE	---		---		---
TV DISPLAY	Included		17.3 lbs. 11.0 x 14.9 x 13.7		
EXPANSION	---		---		
MODEM	Plug-In Card		---		
DISK DRIVE - SMALL	Apple Disk II 3.0 lbs. 3.25 x 5.75 x 8.0		Mounted Internally; 2 Disks Add 7 lbs. to System Unit		
THERMAL PRINTER	6.0 lbs. 2.75 x 7.75 x 12.25		---		---
IMPACT PRINTER	---		12.5 lbs. 4.3 x 15.7 x 14.5		4 ballpoint colors (red/ blue/green/ black)
KEYBOARD (if Separate)	---		6.1 lbs. 2.2 x 19.6 x 7.9		

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WEIGHT/SIZE

	PANASONIC/ QUASAR HHC		EPSON HX-20		HP 75C
CPU (size = in. H x W x D)	1.875 x x 8.9375 x 3.75 1.25 lbs.		1.75 x 10.0 x 8.5		1.25 x 10.0 x 5.0 1.625 lbs.
TAPE					
TV DISPLAY	---		---		---
EXPANSION					
MODEM					Built-in Direct Connect Modem
DISK DRIVE - SMALL					---
THERMAL PRINTER			---		
IMPACT PRINTER	---		Included		---
KEYBOARD (if Separate)	---		---		---

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WEIGHT/SIZE

	TRS-80 MODEL 100				
CPU (size = in. H x W x D)	11.625 x 8.25 x 2.0 3.875 lbs.				
TAPE	---				
TV DISPLAY	---				
EXPANSION					
MODEM	Built-in Direct Connect Modem				
DISK DRIVE - SMALL	---				
THERMAL PRINTER	---				
IMPACT PRINTER	Line Printer VIII - 16.5 lbs; 4.7 x 15.4 x 11.0				
KEYBOARD (if Separate)	---				

BENCHMARK TESTS

A benchmark test consists of running a sequential series of programs that put a computer 'through its paces'. Doing this to two or more computers allows comparison of execution speeds to be made. The benchmark tests used here are all written in BASIC. They do not necessarily provide accurate estimates of the relative speed of the machine using other languages or machine code.

- o Programs 1-7 are based on work done by Tom Rugg and Phil Feldman, Kilobaud, June, 1977. (Data taken on new systems - 1982.)
- o Benchmark tests were designed incrementally to allow comparison both across and within systems by different instructions.

* Exact equivalence for some tests was not possible due to different instruction sets. Programs 8-10 were designed to provide rough comparison for disk access. Times reported were for empty disks.

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PROGRAM LISTINGS

Program 1:

```
300  PRINT "START"
400  FOR K=1 to 5000
500  NEXT K
700  PRINT "END"
800  END
```

Program 2:

```
300  PRINT "START"
400  K=0
500  K=K+1
600  IF K<500 THEN 500
700  PRINT "END"
800  END
```

Program 3:

```
300 PRINT "START"
400  K=0
500  K=K+1
510  A=K/K*K+K-K
600  IF K<500 THEN 500
700  PRINT "END"
800  END
```

Program 4:

```
300  PRINT "START"
400  K=0
500  K=K+1
510  A=K/2*3+4-5
600  IF K<500 THEN 500
700  PRINT "END"
800  END
```

Program 5:

```
300  PRINT "START"
400  K=0
500  K=K+1
510  A=K/2*3+4-5
520  GOSUB 820
600  IF K<500 THEN 500
700  PRINT "END"
800  END
820  RETURN
```

Program 6:

```
300  PRINT "START"
400  K=0
430  DIM M(5)
500  K=K+1
510  A=K/2*3+4-5
520  GOSUB 820
530  FOR L=1 TO 10
540  NEXT L
600  IF K<500 THEN 500
700  PRINT "END"
800  END
820  RETURN
```

Program 7:

```
300  PRINT "START"
400  K=0
430  DIM M(10)
500  K=K+1
510  A=K/2*3+4-5
520  GOSUB 820
530  FOR L=1 TO 10
535  M(L)=A
540  NEXT L
600  IF K<500 THEN 500
700  PRINT "END"
800  END
820  RETURN
```

Program 8:

```
300  PRINT "START"
400  K=0
500  K=K+1
510  A=K/2*3+4-5
515  D$=CHR$(4)
521  PRINT D$;"OPEN SAMPLEX"
522  PRINT D$;"DELETE SAMPLEX"
523  PRINT D$;"OPEN SAMPLEX"
524  PRINT D$;"WRITE SAMPLEX"
525  PRINT "PUTTING 2 STRINGS"
526  PRINT "ONTO THE DISK"
530  FOR L=1 TO 10
531  PRINT L
540  NEXT L
541  PRINT D$;"CLOSE SAMPLEX"
600  IF K<10 THEN 500
700  PRINT "END"
800  END
```

Program 9:

```
300  PRINT "START"
400  K=0
500  K=K+1
510  A=K/2*3+4-5
521  OPEN"O",1,"SAMPLEX"
522  CLOSE1
523  KILL "SAMPLEX"
524  OPEN"O",1,"SAMPLEX"
525  PRINT #1,"PUTTING 2 STRINGS"
526  PRINT #1,"ONTO THE DISK"
530  FOR L=1 TO 10
531  PRINT #1,L
540  NEXT L
541  CLOSE1
600  IF K<10 THEN 500
700  PRINT "END"
800  END
```

Program 10:

```
300  PRINT "START"
400  K=0
500  K=K+1
510  A=K/2*3+4-5
521  OPEN"O",1,"SAMPLEX"
522  CLOSE 1
524  OPEN"O",1,"SAMPLEX"
525  PRINT #1,"PUTTING 2 STRINGS"
526  PRINT #1,"ONTO THE DISK"
530  FOR L=1 TO 10
531  PRINT #1,L
540  NEXT L
541  CLOSE1
600  IF K<10 THEN 500
700  PRINT "END"
800  END
```

BENCHMARK TESTS

	TRS-80 MODEL III		COMMODORE 64		APPLE II
P1	13.0				6.5
P2	5.3				4.1
P3	(P2 + 6.7)				7.7 (P2 + 3.6)
P4	12.7 (P2 + 7.4)				8.6 (P2 + 4.5)
P5	14.2 (P4 + 1.5)				9.3 (P4 + 0.7)
P6	30.6 (P5 + 16.4)				17.5 (P5 + 8.2)
P7	55.1 (P6 + 24.5)				33.7 (P6 + 16.2)
P8 *	---				49.6
P9 *	---				---
P10 *	56.7				---

BENCHMARK TESTS

	APPLE IIe		IBM PERSONAL COMPUTER (WITH COLOR BD)		SHARP PC-1500
P1			6.4		73.3
P2			2.8		15.3
P3			6.3 (P2 + 3.5)		39.9 (P2 + 24.6)
P4			6.6 (P2 + 3.8)		39.9 (P2 + 24.6)
P5			7.1 (P4 + 0.5)		47.3 (P4 + 7.4)
P6			15.1 (P5 + 8.0)		119.6 (P5 + 72.3)
P7			29.0 (P6 + 13.9)		175.6 (P6 + 56.0)
P8 *			---		---
P9 *			132.6		---
P10 *			114.9		

BENCHMARK TESTS

	PANASONIC/ QUASAR HHC		EPSON		HP75
P1	6.5		12.9		
P2	4.5		7.45		
P3	7.6 (P2 + 3.1)		16.2 (P2 + 8.75)		
P4	8.5 (P2 + 4.0)		16.25 (P2 + 8.8)		
P5	9.2 (P4 + 0.7)		17.35 (P4 + 1.1)		
P6	17.2 (P5 + 8.0)		37.35 (P5 + 20.0)		
P7	33.0 (P6 + 15.8)		77.70 (P6 + 40.35)		
P8 *	---		---		
P9 *	---		---		
P10 *			---		

BENCHMARK TESTS

TRS-80 MODEL 100

P1	16.36				
P2	5.27				
P3	13.18 (P2 + 7.91)				
P4	15.12 (P2 + 9.85)				
P5	16.0 (P4 + .88)				
P6	30.7 (P5 + 14.7)				
P7	47.0 (P6 + 16.3)				
P8 *					
P9 *					
P10 *					

COST COMPARISONS

No specific cost information is provided, since prices in this area are very volatile, and change too fast to print in any reference manual. The various blanks are provided to offer suggestions as to prices to check on. Some notes are provided for a few example computers, regarding what is or is not included in the price. A few guidelines when costing computers:

1) Be sure that you get the price for the complete computer system as you want to use it. Some computers have a low price, but do exclude so many necessary components that the price doubles or more by the time you put the "wheels and doors on the car".

2) Be sure that you add up your software costs. Some computers come complete with software, while others do not. A computer with software is like a record player without records. Software also can cost as much or more than your computer.

3) Do not plan on using your home TV set as a display unless you are going to have less than 80 characters across the screen. You can double-check this with your supplier for individual computers.

COST

	TRS-80 MODEL III		COMMODORE 64		APPLE II
CPU	$ (48K) $ (48K w/ 2 drives)		$ (64K)		Out of prod.; avail. used;
EXPANSION	Provisions for 48K, RS-232		---		8 Slots Included
TAPE	$		$		Alternate Manufaoturer
TV DISPLAY	Included		Alternate Manufacturer		---
+32K RAM	$ 16K				$
80 CHAR/LINE	---		Alternate Manufacturer		Alternate Manufaoturer
UPPER/LOWER CASE	Incl. only w/ Mod III Basic		Included		Alternate Manufaoturer
FIRST DISK SIZE (BYTES)	$ 185K		$ 160K		$ 143K
DOS	Incl. w/1st drive; Add'l DOS disk $		Included		Included
SECOND DISK SIZE (BYTES)	$ 175K		Same As First		$ 143K
3rd & 4th DISK SIZE (BYTES)	$ 175K (External)		Same As First		Same as First and Second
RS-232 SERIAL	$				$
GAME INPUTS	---		Inputs for 1 X-Y Joystick		2 Paddle (or 1 Joystick) Inputs Incl.
PARALLEL PORT	1 Printer Port Included				$

	TRS-80 MODEL III		COMMODORE 64		APPLE II
SPEAKER	---		Included		Included
TTL INPUTS	---				3 Included
TTL OUTPUTS	---				4 Included
ANALOG INPUTS	---		2 Joystick Inputs		2 Paddles or 1 Joystick
NUMBER PAD	Included		---		---
BUS ACCESS	1		1		8 Slots

	APPLE IIe		IBM PERSONAL COMPUTER (WITH COLOR BD)		SHARP PC1500/ RADIO SHACK PC2
CPU	CPU only $ 64K pkg $ 128K pkg $		$ (64K) $ (64K w/ 2 drives)		$ (16K ROM and 3.5K RAM)
EXPANSION	8 Slots Included		5 Slots Included		$ (8K) $ (16K)
TAPE	Alternate Manufacturer		---		Printer & tape $ + $
TV DISPLAY	Gr.phsph. Mon. incl. in pckg.		Monochrome- $ + $, Color-Alt Mnfr		N/A
+32K RAM	$ 64K		$ 64K		---
80 CHAR/LINE	Included in package		Included		N/A
UPPER/LOWER CASE	Included in package		Included		Included
FIRST DISK SIZE (BYTES)	Included in pckg; 143K		Built In 5 1/4" Floppy 320K		---
DOS	Included in package		$		---
SECOND DISK SIZE (BYTES)	$ 143K		$ 320K		---
3rd & 4th DISK SIZE (BYTES)	Same as second		---		---
RS-232 SERIAL	$		Included		Included
GAME INPUTS	4 Joystick Inputs Included		$ (Game Control Adapter)		
PARALLEL PORT	$		1 Parallel Printer Port Included		Included

	APPLE IIe		IBM PERSONAL COMPUTER (WITH COLOR BD)		SHARP PC1500/ RADIO SHACK PC2
SPEAKER	Included		Included		
TTL INPUTS	3 Included		4 Analog & 4 Digital Game Contol Adpt.		
TTL OUTPUTS	1 Included		---		
ANALOG INPUTS	4 Inputs		2 X-Y Joysticks, or 4 Paddles		
NUMBER PAD	$		Included		Included
BUS ACCESS	8 Slots		5 Slots		1

COST

	PANASONIC/ QUASAR HHC		EPSON HX-20		HP 75C
CPU	$ (2K) $ (4K)		$ (16K) $ (32K)		$ (Incl. 16K RAM and 48K ROM)
EXPANSION	$ (4K) $ (8K)		$ (16K)		8K RAM Module $
TAPE	---		$ reg.;$ micro (30-90K)		Builtin 1.3K magn.str.holder
TV DISPLAY	$ (+TV; $)		$ to be announced		$
+32K RAM	---		---		---
80 CHAR/LINE	N/A		N/A		N/A
UPPER/LOWER CASE	Included		Included		Included
FIRST DISK SIZE (BYTES)	---		---		---
DOS	---		---		---
SECOND DISK SIZE (BYTES)	---		---		---
3rd & 4th DISK SIZE (BYTES)	---		---		---
RS-232 SERIAL	(RD-9145) $		Included		$
GAME INPUTS					
PARALLEL PORT	(Bus)		(Bus)		

COST

	PANASONIC/ QUASAR HHC		EPSON HX-20		HP 75C
SPEAKER	Included		Included		Included
TTL INPUTS					
TTL OUTPUTS					2 HP-IL Cbles Included
ANALOG INPUTS					
NUMBER PAD	---		---		---
BUS ACCESS	1 (6 w/expnsn)		1 parallel 1 serial		1 serial loop

COST

	TRS-80 MODEL 100				
CPU	$ (8K) $ (24K) $ (32K)				
EXPANSION	$ (8K)				
TAPE	$				
TV DISPLAY	---				
+32K RAM	$				
80 CHAR/LINE	N/A				
UPPER/LOWER CASE	Included				
FIRST DISK SIZE (BYTES)	---				
DOS	---				
SECOND DISK SIZE (BYTES)	---				
3rd & 4th DISK SIZE (BYTES)	---				
RS-232 SERIAL	Included				
GAME INPUTS					
PARALLEL PORT					

COST

	TRS-80 MODEL 100				
SPEAKER	Included .				
TTL INPUTS					
TTL OUTPUTS					
ANALOG INPUTS					
NUMBER PAD	Included				
BUS ACCESS					

REVIEW OF DESIRED CHARACTERISTICS

REVIEW OF DESIRED CHARACTERISTICS

OVERVIEW

It is impossible to cover each of the computers currently available in terms of each of these characteristics. We will therefore discuss the characteristics using a common set of computers which are available today, and which exemplify the different basic approaches to computer implementation at this time. You can extrapolate these comments to any other computers which you are considering.

INPUT CHARACTERISTICS

KEYBOARDS

Detachable Keyboards: There are two possible reasons for wanting a detachable keyboard. The first is to allow more optimum positioning of the keyboard to facilitate use by the handicapped individual. Keyboards which are connected to computers can be quite difficult to tilt at sharp angles or to mount remotely.

The second advantage of a detachable keyboard is that it facilitates the application of keyboard emulators. Keyboard emulators are modules which go between the keyboard and the computer and allow other communication aids (or computers) to control the computer in a totally transparent fashion (see Appendix B). In this fashion, any standard software can be used on a computer without requiring any modifications. The usefulness of a detachable keyboard stems from the fact that a keyboard emulator can be added to the system without having to open up the computer and disconnect internal wiring. However, the advantage of having a detachable keyboard for this purpose only exists if a keyboard emulator is available for the particular computer in question. Some computers have simple keyboard encoding schemes which allow keyboard emulators to be easily fabricated. Others have more complicated approaches. The IBM personal computer, for example, has a microprocessor directly inside the keyboard, and information is sent back and forth to the main computer in a complex serially encoded fashion. The Epson QX10, on the other hand, uses standard serial RS232 ASCII, making the keyboard emulator trivial or unnecessary, depending upon the aid being used with it.

In addition, there are a number of portable computers that they are in effect not much larger than a keyboard. They are therefore just as repositionable as if they had detachable

keyboards. This does not facilitate the keyboard emulation problem, however. All of the portable computers reviewed fall into this category.

Feedback from Keys: Most keyboards have good tactile feedback from the keys. Some elastomeric keyboards, such as the Atari 400, however, provide no tactile indication that the keys have been pressed. Instead, the Atari 400 provides an audible beep. Clinical work has shown that keyboards without some type of clear feedback result in slower access times by individuals due to the uncertainty of the actuation keys and the consequent frequent references to the display feedback. When there is question as to the adequacy of the feedback from the keyboards, some type of audible feedback can be added, and the individual's rates on the various keyboards evaluated. The best method, of course, is direct comparison of the individual's rates on the various keyboards. When doing this, it is suggested that six keys in the same location on all keyboards be marked with red or green spots. The individuals can then be timed to determine how long it takes to hit these clearly marked keys. In this manner, the variances in keyboard arrangements and the individual's lack of familiarity with the keyboard arrangements will have minimal effect on the results of the timing.

Keyboard size: A common misconception has been that the more severe the person's physical disability, the larger the keyboard required. Clinical work, however, has shown just the opposite to be true in many cases. Careful evaluation on the various keyboard sizes is therefore recommended.

Keyboards can in general be broken down into three categories: full size keyboards, miniature keyboards, and sub-miniature keyboards. Most of the non-portable aids have either full size keyboards or keyboards which are approximately the same size. The portable Epson HX20 and TRS-80 Model 100 have standard size keyboards. The HP75 has a slightly smaller keyboard, but is still advertised as "touch typable".

Shift Lock Keys: As mentioned previously, shift lock keys are of little value unless control lock keys are also provided. Since none of the computers have control lock keys, some special modification is required to allow the individuals to activate the control keys. The same mechanism could also be applied to the shift keys. Some computers also have a "CAPS LOCK" key. However, this does not allow the individual to handle the other shift characters such as those above the numbers, since this key only affects the letter keys.

Some of the portable computers, however, have shift keys with a built-in memory. These computers, which are designed for one-finger operation, do not present the problem to one-fingered typists or headstick typists that the normal keyboards do. It should be noted that the HP75, although considered a portable computer, does not have a shift key with a memory. The shift

key must be held down while activating the other key(s). It should also be noted that some of the more portable computers, such as the Sharp 1500 and the Radio Shack PC2 do not have a control key. Thus the control lock problem is eliminated. The Panasonic/Quasar HHC has both shift and control keys with memory, allowing full one-finger access.

Some computers (such as the Epson and the Sharp) do have software-polled keys, which include the shift and control keys. With these computers, special programs can be written to treat the shift and control keys as keys with a memory. This capability can be taken advantage of in specially written software, but will not help the handicapped individual when trying to operate standard software packages.

Keyguard Availability: This is currently an area of concern, since only a couple of computers have commercially available keyguards (the Apple II and the TRS-80 Model III). This should change rapidly, however, as other computers receive more widespread application in this area. Keyguards can also be fabricated fairly easily for most keyboards, although shift and control key hold-down mechanisms are somewhat more difficult to fabricate. (Perhaps the easiest shift and control key hold-down mechanisms are weights on hinges, which the individual can tip back and forth.)

Keyboard Emulator Availability: This is a crucial element if transparent access to the computer is to be provided. At the present time, most of the keyboard emulators are available for the Apple II. Keyboard emulators are under development for several other brands, however. (As these are completed and become available, they will be listed in the Trace Center International Hardware/Software Registry.)

SWITCH INPUTS

For some individuals, computers will need to be interfaced with single- or two-switch interface techniques. Some computers, such as the Atari, the TRS-80 Color, the Apple, the Commodore 64, and the Commodor Vic have special switch inputs available on them. Other computers, such as the IBM, TRS-80 Model III, and PET, have adaptors available to allow them to handle switches. For those computers which do not have specific switch input capability, fairly simple modifications can be made to allow switch input jacks to be wired in parallel with one or two keys on the keyboard. The activation of the switch would then look to the computer as though one of the keys was being activated. This technique will not work with keyboards such as the capacitive keyboard found on the IBM computer. This type of modification will also void the warranty. Many individuals, however, just wait for the warranty to run out, and then make the modifications. In other cases, the computer manufacturers have honored the warranty even with the modifications in place, where a) the modification was not the cause of the problem, and b) a note is included describing the circumstances and the reason for the modification.

Analog Input: For some individuals, the use of a joystick may facilitate the use of the computer. The Atari, Apple, Commodore 64, and Commodore Vic all have analog or joystick inputs standard. Several other computers, such as the IBM, Xerox, etc., have game paddle adaptors to allow them to handle simple analog joystick input. Other types of analog input can also be handled by many of the computers using special analog-to-digital (A-D) converter modules. These are most commonly available for computers such as the Apple and IBM, which have built-in accessory slots.

Light Pen: The light pen input can be useful for computer applications for retarded individuals and other individuals for whom direct pointing to the screen is the best approach. A touch-sensitive screen in these cases would probably be more effective, but also more expensive. Some of the computers have built-in lightpen capabilities. Among these are the Vic, Atari, Commodore 64, Pet, Apple II, IBM, and Xerox. In addition, a new long-range lightpen has been developed which can be used from as much as three feet from the screen with as good as one pixel resolution (Trace Center, Madison, Wisconsin). With this lightpen, headpointing communication aids can be designed. This long range lightpen can be used with computers such as the Vic or Atari which have medium resolution (4-5 pixel) lightpen capabilities built in. In addition, a version of the long range lightpen is also being fabricated which will work with any computer having a standard TV monitor display and RS232 serial ASCII port. Thus, the presence of built-in lightpen capability is not crucial, although it may reduce costs in some applications.

FEEDBACK CHARACTERISTICS

DISPLAY

Character Size: Most of the stationary computers have CRT displays. The size of the characters is dependent both on the size of the actual TV display used and the number of characters displayed. Some systems use built-in or custom CRT displays. These include the Pet CBM, IBM, and Xerox computers. In these cases, it is not as easy to enlarge the display for a given individual by hooking up larger TV monitors. Most of the other computers, however, do use standard CRT monitors, and the size of the display can be easily controlled by choosing a larger screen TV set or monitor. In addition, some newer TV sets/monitors have a zoom capability which can allow individuals to zoom in on various portions of the screen. On the portable computers, the size of the characters is again proportion to the number of characters on the display. The Epson has the largest characters, although the HHC, Sharp and HP75 are very close. The TeleRam has smaller characters, due to the number of characters contained in its display.

Active vs. Passive Lighting Display: All of the stationary computers use a CRT monitor type of display. All of these are active, luminous displays. On the other hand, all of the portable, hand-held computers use LCD displays. These displays are passive, and therefore somewhat more difficult for an individual to see given the same size character. In addition, these characters cannot be read using an Opticon.

Upper/Lower Case Capability: All of the computers reviewed have upper and lower case capability with the exception of the Apple II computer. Adaptations are available for the Apple II to provide upper and lower case, but it is not supported in all software. A newer version of the Apple II, the Apple IIe, is available which does have upper and lower case.

AUDIO FEEDBACK

"Click" Feedback: This feedback is really only necessary on the keyboards which have very poor tactile feedbak. Only the the Atari computers have elastomeric keyboards. Click feedback is provided with this computer.

Speech Feedback: None of the computers have speech feedback which runs in the background with all standard software. All of the computers have either an RS232 port or a provision for attaching one. All of the computers can therefore be used with the stand-alone speech synthesizers currently available on the market. At the present time, however, there are no portable speech synthesizers. The use of speech synthesizers with the portable computers is thus of only limited value at this time. This should be changing fairly soon, however.

ABILITY TO MEET NEEDS

OUTPUTS

Correctable Displays: All of the computers have correctable displays.

Number of Characters per Line: The best aids with regard to the number of characters per line are the business computers, which have a full 80 characters per line. These include the Apple III, IBM, and Xerox. The TRS-80 Model III with its 64 character line is close behind. Most of the other stationary computers have either 40 or 32-character displays. The exception is the Commodore Vic, which has only a 22 character display. With the portable aids, the best display is the Model 11, which has a full 40 character display. The HP75 has a 32 character display; the HHC a 22 character display; the Sharp 1500 a 22-character display; and the Epson a 20-character display. All of the portable aids also have virtual screens, which allow them to

larger effective line length, although the individual can only see the aforementioned number of characters at any one time.

Both the Epson and the HHC have TV display attachments announced. These do, however, eliminate the portability of the systems as the TV displays are not battery powered.

Number of Lines of Text on Display: The best aids in this area are the various stationary aids. These range from 16 to 24 lines, all of which provide quite functional displays for feedback of text and for working mathematics and other manipulative exercises. Of the portable aids, only the Epson and the Model 11 have multi-line displays. The Epson has a 4-line display; the Model 100 has 8. This is sufficient to allow simple two- and three-number high arithmetic problems to be displayed and worked by the individual. This also greatly facilitates the individual's text editing.

Again, both the Epson and the HHC have TV display attachments announced.

High-Resolution Graphics and Color: Most of the stationary computers have some type of graphics. The Pet and Vic computers are limited to character graphics. Most of the other computers either have high-resolution graphics or have adaptors to provide high-resolution graphics. Color is also available on all but the Pet, CPM, and TRS-80 Model III computers. High-resolution graphics in color are usually required only in game or special educational software. They may, however, be useful in providing the individual with the ability to draw. This could be either for creative expression or for employment in such areas as electrical engineering or computer programming, where the ability to draw charts and diagrams is an important component of the field.

Most of the portable computers have graphics capabilities on their miniature screens. Because of the small size of the screens, however, this has only limited applicability. Many of the portable aids, however, do have TV display accessories which can expand their function in a work station situation.

Both the Epson and the HHC have TV display attachments announced. These do, however, eliminate the portability of the systems as the TV displays are not battery-powered.

PRINTED OUTPUT

Thermal/Impact/Ballpoint Printers: All of the computers have built-in RS232 or RS232 accessories for them. As a result, all of the computers can be used with any of the standard character, thermal, or dot-matrix printers.

Most of the portable computers have printers which are either built in or attach to them. The Epson HX20 has a built-in 20

column dot matrix impact printer. The HHC has either a dot matrix printer or a ballpoint printer similar to the ballpoint printer found on the Sharp 1500 and Radio Shack pc2. The dot matrix printers allow printing of characters as well as graphics. The ballpoint printers are actually four-color X-Y plotters. As such, they can draw characters in any of nine sizes and four colors. In addition, they can write letters upside down and backwards, as well as draw very clear and accurate charts, diagrams, and pictures.

Speed: This is mostly a function of the printer purchased. Since most of the printers are interchangeable among computers, the speed of the printer is not generally a deciding factor in selecting a particular computer.

Paper Width: Although full-width, 80-column page width is generally thought to be the most desirable, it is not always the optimal size for portable aids. In order to have an 80-column printer, a fairly large roll of paper is required, as well as a large print mechanism. This adds to both the bulk and the weight of the portable system. For portable writing aids, therefore, a smaller display is not only the only thing available, but also the optimal. The ballpoint printers have the unique ability of allowing variable number of characters per line to better allow the individual to adjust the size of the printing and the number of characters per line to match the specific application. The HHC has perhaps the best printer in this regard in that it can handle approximately half-page width paper, which can hold either a half-page width of normal sized characters, or a full line length of smaller characters. This allows a "what you see is what you get" printout on the portable printer, which could be later printed out on a full size printer if desired. A smaller version of this same printer is available on the Sharp 1500/Radio Shack pc2. The Epson HX20 is limited to a dot matrix printer on a 2"-wide paper tape. This is a more compact printer, but does have limitations of width as well a single character size.

Graphics Capability: All of the hand-held computers have graphics capability on their printers. Graphics printers are available for all of the stationary computers as well in order to match the graphics capabilities of the computers.

OTHER OUTPUT FORMS

Phone Modems: Phone modems are available for all of the computers listed.

PROCESSING AND STORAGE

STORAGE

Disk Drives: All of the stationary computers have disk drives. In addition, disk drives are announced for the HP75, the Epson, and the HHC portable computers. These disk drives, however, do not run off batteries, and therefore extend the capabilities of the portable computers as work stations but not as portable computers per se.

CMOS RAM: Normally, when a computer is turned off it forgets all of its program. Use of CMOS RAM, however, allows the computer to remember the program even when it is turned off. In this fashion, simply turning the power on will cause the computer to come up running with all of the memory, vocabulary, etc., still in the computer. For stationary computer systems which have disk drives, this feature is not as important, since the information can be easily be stored on the disk and retrieved when the computer is turned on. For the portable computers, however, which do not have disk drives, this is an important capability. All of the portable computers reviewed have CMOS memory, and retain their programs when they are turned off.

TRANSPORTABILITY

Clearly, the most transportable computers are the hand-held or portable computers. Some of these are quite small (e.g., the Sharp 1500 and the HHC) but grow rapidly in size as accessories are added. Others, such as the Epson, have all of their capabilities, including tape drive, display, and printer, built into a single unit. In looking at the tranportability of the system, the overall size and weight should be considered, as well as the number of components and the need to assemble or disassemble the system for transport.

Some of the non-portable computers are also quite transportable. The Spectrum, for example, can almost fit into your pocket, but does require a television set and a power supply in order to run. With most of the stationary systems, the need to have multiple components and a television screen makes them movable but not easily transported back and forth on a daily basis. For systems where the television display is far and away the largest obstacle to transportability, a number of television sets can be secured and placed at school and home, as well as any other major areas of use for the computer. The individual can then simply carry the computer and tape or disk drive around with him. If the individual also needs a printer, the pieces quickly accumulate. One mechanism which can be used to overcome this with some of the smaller systems, such as the Spectrum, Vic, Atari, and TRS-80 Color, is to bolt the various components to a board or lid of a case. They then become a single unit, which is more easily carried from place to place. (Again, the TV set is usually not included in this type of package, but is either carried separately or left behind in each location.)

MODULARITY

Of the portable computers, the least modular is the Epson, and the most modular is either the HHC or the HP75, although the Sharp 1500/Radio Shack PC-2 is in this category as well. Of the stationary computers, most of the systems are quite modular, with the exception of the Pet/CPM and Xerox computers. In these cases, however, the modularity does not affect the repairability as much as it does the transportability as discussed above.

WIDE DISTRIBUTION/REPAIR NETWORKS

This used to be a large area of concern in the early days of microcomputers. With most of the more popular brands, however, the maintenance is fairly widespread and easily available. Some brands, such as the Radio Shack and Apple computers, still enjoy a much larger service base, especially on a local basis. Computers such as the IBM and Xerox, however, are also serviced well because of the necessity for providing rapid service to business customers.

ABILITY TO CUSTOMIZE

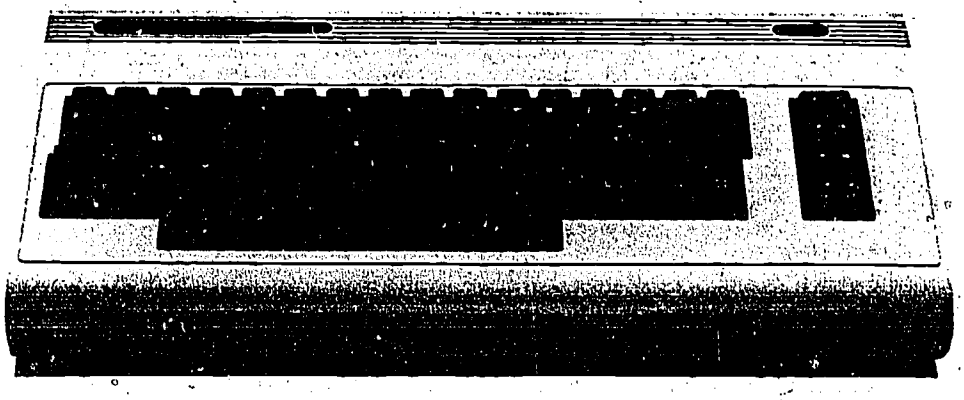
The superior computers in this category are the Apple and IBM computers. Both of these computers have built-in adaptor slots which are easily accessible and heavily documented. This allows custom modifications to be made easily which can plug directly into the computer, sharing the computer's power supply and housing. Modifications to the other computers generally involve gerry-rigged/piggy-backed boards within the computer or separate custom modules which must be fabricated and attached to the outside via a cable.

AVAILABILITY OF DESIRED MODIFICATIONS

At the present time, most special modifications for handicapped individuals is available for the Apple computer. The TRS-80 Model III is also quite popular. The Model III, however, is generally more heavily supported with special software, whereas the Apple has a wealth of both software and hardware modifications - again because of its easy hardware accessibility.

REVIEW OF DESIRED CHARACTERISTICS BY COMPUTER

The following pages give a brief overview of the computers used in this report in terms of the characteristics discussed in the previous section. Again, this is a rapidly changing field, so some of the data may well have changed by the time you read this. These profiles are included to provide guidelines as you compare candidate computers.



COMMODORE VIC

OPERATIONAL CHARACTERISTICS
- INPUTS
  - KEYBOARDS
    - Separable keyboard: Not separable, but entire computer small and repositionable.
    - Feedback from keys: Full size keyboard with tactile feedback. No audible feedback.
    - Keyboard size: Full standard keyboard.
    - Shift/lock keys: Shift lock yes; no control lock
    - Keyguard availability:
    - Keyboard emulator availability:
  - SWITCH INPUTS: 4 discrete or 12 in X-Y matrix.
  - ANALOG INPUTS: 4 resistive analog inputs.
  - LIGHTPEN: Character resolution lightpen circuitry provided.

FEEDBACK CHARACTERISTICS
- DISPLAY
  - Character size: Large for display.
  - Active/Passive lighting display: CRT display
  - Upper/lower case capability: Yes
- AUDIO FEEDBACK
  - 'Click' feedback: Normally none.
  - Speech feedback: Will connect to standard RS232 speech output devices.

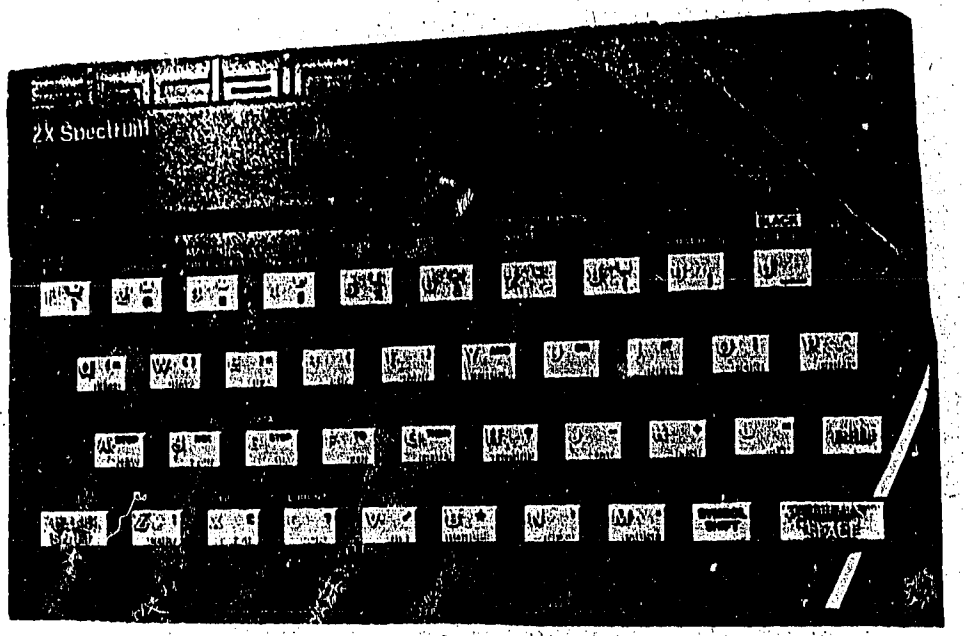
REVIEW OF DESIRED CHARACTERISTICS BY COMPUTER

ABILITY TO MEET NEED
OUTPUTS
CORRECTABLE DISPLAYS
Correctabilities: Correctable CRT display
characters/line: 22
lines of text on display: 23
High resolution graphics/color: No high resolution graphics, but color.
PRINTED OUTPUT
Printers: Any RS232 printer.
OTHER OUTPUT FORMS
Phone modems: Special low-cost modem available.
PROCESSING AND STORAGE
STORAGE
Disk drives: Yes.
CMOS RAM: No.
Computer memory size: 5-16K
TRANSPORTABILITY: Can be easily transported, but is not portable, and does require a CRT display.

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
MODULARITY: Minimal
WIDE DISTRIBUTION/REPAIR NETWORKS: Moderate
ABILITY TO CUSTOMIZE: Minimal
AVAILABILITY OF DESIRED MODIFICATIONS: Few special modifications available.

OTHER COMMENTS

This is not the most powerful computer in its price range. It does, however, have a full-size keyboard. All peripherals for the VIC 20 also work with the Commodore 64, which is quite a powerful machine for its price.



SINCLAIR SPECTRUM

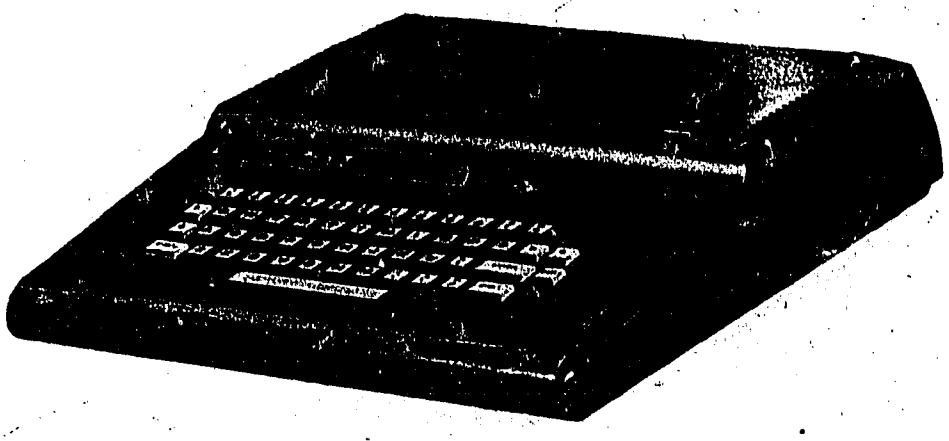
OPERATIONAL CHARACTERISTICS
 INPUTS
  KEYBOARDS
   Separable keyboard: Not separable, but entire computer small and repositionable.
   Feedback from keys: Fair
   Keyboard size: Small
   Shift/lock keys: All shift keys have memory for one-finger typing.
   Keyguard availability: ---
   Keyboard emulator availability: ---
  SWITCH INPUTS: ---
  ANALOG INPUTS: ---
  LIGHTPEN: ---
 FEEDBACK CHARACTERISTICS
  DISPLAY
   Character size: Moderate; depends on TV size
   Active/Passive lighting display: CRT display
   Upper/lower case capability: Yes
  AUDIO FEEDBACK
   'Click' feedback: Yes
   Speech feedback: Will connect to standard RS232 speech output devices.

ABILITY TO MEET NEED
OUTPUTS
CORRECTABLE DISPLAYS
Correctabilities: Correctable CRT display
characters/line: 32
lines of text on display: 24
High resolution graphics/color: Yes
PRINTED OUTPUT
Printers: Special low-cost ($90.00) printer, or any RS232 printer.
OTHER OUTPUT FORMS
Phone modems: Yes
PROCESSING AND STORAGE
STORAGE
Disk drives: Announced; not available
CMOS RAM: No.
Computer memory size: 5-16K
TRANSPORTABILITY: Good, but uses CRT screen and requires wall power

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
MODULARITY: Minimal
WIDE DISTRIBUTION/REPAIR NETWORKS: Minimal to moderate; improving
ABILITY TO CUSTOMIZE: Minimal
AVAILABILITY OF DESIRED MODIFICATIONS: Minimal

OTHER COMMENTS

This is a very powerful computer for its size and price. In addition, a very low-cost disk and printer have been announced. This will probably be the lowest priced complete computer system (including disk) with similar capabilities. THe keyboard is, however, quite small, and the system is not portable, although it is highly transportable.



TRS-80 COLOR

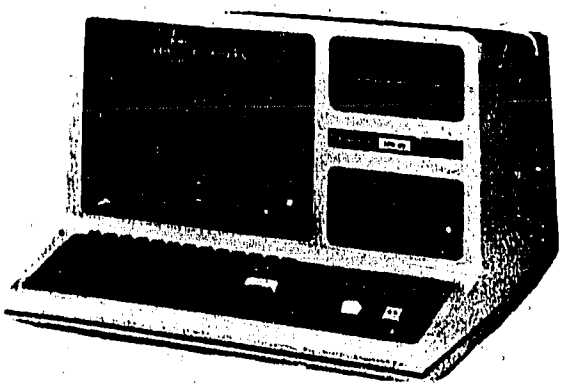
OPERATIONAL CHARACTERISTICS
 INPUTS
  KEYBOARDS
   Separable keyboard: No.
   Feedback from keys: Good, but not as good as standard keyboard.
   Keyboard size: Approximately normal.
   Shift/lock keys: Shift and control keys must be held down while activating other key.
   Keyguard availability:
   Keyboard emulator availability:
  SWITCH INPUTS: Yes.
  ANALOG INPUTS: Yes.
  LIGHTPEN: Alternate manufacturer
 FEEDBACK CHARACTERISTICS
  DISPLAY
   Character size: Moderate.
   Active/Passive lighting display: Active - CRT display
   Upper/lower case capability: Upper case only.
  AUDIO FEEDBACK
   'Click' feedback: Not normally.
   Speech feedback: Will connect to standard RS232 speech output devices.

ABILITY TO MEET NEED
 OUTPUTS
  CORRECTABLE DISPLAYS
   Correctabilities: Correctable CRT display
   # characters/line: 32
   # lines of text on display: 16
   High resolution graphics/color: High resolution graphics; color
  PRINTED OUTPUT
   Thermal/impact/ballpoint pen printers: Any RS232 printer.
   Graphics capability: Yes
  OTHER OUTPUT FORMS
   Phone modems: Yes
 PROCESSING AND STORAGE
  STORAGE
   Disk drives: Yes
   CMOS RAM: No
  TRANSPORTABILITY: Moderate; not portable, and does require a CRT display.

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
  MODULARITY: Minimal
  WIDE DISTRIBUTION/REPAIR NETWORKS: High
  ABILITY TO CUSTOMIZE: Minimal
  AVAILABILITY OF DESIRED MODIFICATIONS: Moderate

OTHER COMMENTS

Light, portable device. Suitable for special software programs, but not well suited for special hardware modifications. No expansion slots provided (although bus is provided). Unit has only upper case, and has no provision to allow for upper and lower case except by drawing the characters through high-resolution graphics software. (The character generator PROM is built into the video chip.)



TRS-80 MODEL III

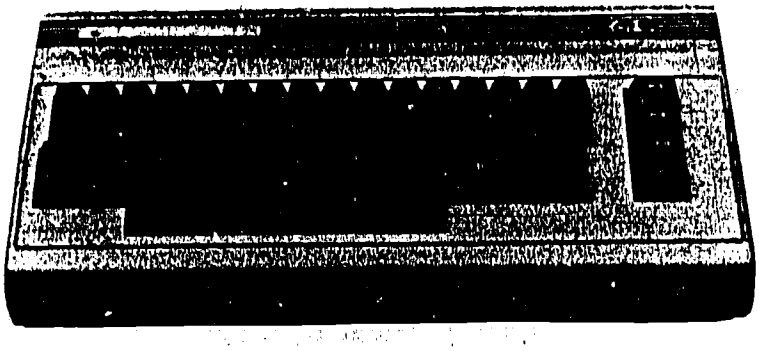
OPERATIONAL CHARACTERISTICS
- INPUTS
  - KEYBOARDS
    - Separable keyboard: No
    - Feedback from keys: Standard
    - Keyboard size: Standard
    - Shift/lock keys: Shift and control keys must be held down while activating other key.
    - Keyguard availability: Keyguards available
    - Keyboard emulator availability:
  - SWITCH INPUTS: ---
  - ANALOG INPUTS: ---
  - LIGHTPEN: Alternate manufacturer
- FEEDBACK CHARACTERISTICS
  - DISPLAY
    - Character size: Moderate
    - Active/Passive lighting display: Active -- CRT display
    - Upper/lower case capability: Yes
  - AUDIO FEEDBACK
    - 'Click' feedback: Not normally
    - Speech feedback: Will connect to standard RS232 speech output devices.

ABILITY TO MEET NEED
 OUTPUTS
  CORRECTABLE DISPLAYS
   Correctability: Correctable CRT display
   # characters/line: 32 or 64
   # lines of text on display: 16
   High resolution graphics/color: High resolution graphics; no color
  PRINTED OUTPUT
   Printers: Any RS232 printer.
   Graphics capability: Yes
  OTHER OUTPUT FORMS
   Phone modems: Yes
 PROCESSING AND STORAGE
  STORAGE
   Disk drives: Yes
   CMOS RAM: No
  TRANSPORTABILITY: Minimal; stationary, contains CRT display

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
  MODULARITY: Minimal
  WIDE DISTRIBUTION/REPAIR NETWORKS: High
  ABILITY TO CUSTOMIZE: Minimal
  AVAILABILITY OF DESIRED MODIFICATIONS: Moderate

OTHER COMMENTS

The Model III is a good basic computer for business-type applications. It has high-resolution graphics, but its lack of color limits its use in special software situations, especially with young children. Application in rehabilitation would generally revolve around special software-implemented routines rather than hardware-implemented routines, due to its lack of expansion ports and special transducer inputs.



COMMODORE 64

OPERATIONAL CHARACTERISTICS
- INPUTS
  - KEYBOARDS
    - Separable keyboard: Not separable, but entire computer small and repositionable.
    - Feedback from keys: Normal
    - Keyboard size: Normal
    - Shift/lock keys: Shift lock; no control lock
    - Keyguard availability:
    - Keyboard emulator availability:
  - SWITCH INPUTS: 4 discrete; 12 X-Y
  - ANALOG INPUTS: 4 resistive analog inputs
  - LIGHTPEN: Yes
- FEEDBACK CHARACTERISTICS
  - DISPLAY
    - Character size: Good; depends on display
    - Active/Passive lighting display: Active -- CRT
    - Upper/lower case capability: Yes
  - AUDIO FEEDBACK
    - 'Click' feedback: Not normally
    - Speech feedback: Will connect to standard RS232 speech output devices.

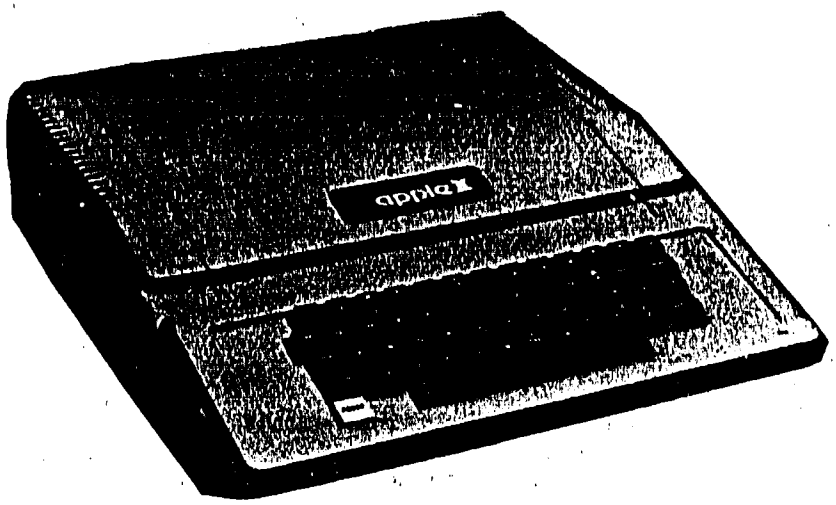
ABILITY TO MEET NEED
 OUTPUTS
  CORRECTABLE DISPLAYS
   Correctability: Correctable CRT display
   # characters/line: 40
   # lines of text on display: 24
   High resolution graphics/color: Yes
  PRINTED OUTPUT
   Printers: Any RS232 printer.
   Graphics capability: Yes
  OTHER OUTPUT FORMS
   Phone modems: Yes
 PROCESSING AND STORAGE
  STORAGE
   Disk drives: Yes
   CMOS RAM: No
  TRANSPORTABILITY: Good

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
  MODULARITY: Fair
  WIDE DISTRIBUTION/REPAIR NETWORKS: Good
  ABILITY TO CUSTOMIZE: Fair to poor
  AVAILABILITY OF DESIRED MODIFICATIONS: Poor (very new)

OTHER COMMENTS

This is a very powerful computer for the price. It includes a standard keyboard. The Commodore 64 uses all of the peripherals of the Vic 20, allowing upward compatability of accessories.

It has a very flexible game paddle input connector which allows for multiple switches and/or joysticks to be connected. It does not have an accessory slot design. It is also quite a new entry to the field, and there are therefore minimal modifications available for it.



APPLE II

OPERATIONAL CHARACTERISTICS
- INPUTS
  - KEYBOARDS
    - Separable keyboard: No
    - Feedback from keys: Standard
    - Keyboard size: Standard
    - Shift/lock keys: Shift and control keys must be held down while activating other key.
    - Keyguard availability: Several keyguards available.
    - Keyboard emulator availability: Several emulators available
  - SWITCH INPUTS: 3 provided.
  - ANALOG INPUTS: 4 provided.
  - LIGHTPEN: Low- and high-resolution lightpens available; alternate manufacturers
- FEEDBACK CHARACTERISTICS
  - DISPLAY
    - Character size: Moderate
    - Active/Passive lighting display: Active; CRT display
    - Upper/lower case capability: No (available through adaptors)
  - AUDIO FEEDBACK
    - 'Click' feedback: Not normally.
    - Speech feedback: Will connect to standard RS232 speech output devices.

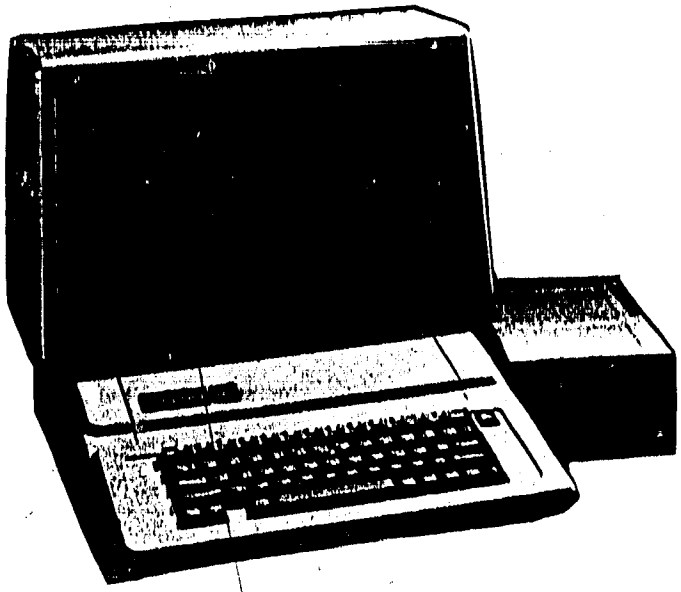
ABILITY TO MEET NEED
 OUTPUTS
  CORRECTABLE DISPLAYS
   Correctability: Correctable CRT display
   # characters/line: 40
   # lines of text on display: 24
   High resolution graphics/color: Graphics yes; color yes
  PRINTED OUTPUT
   Printers: 80-column thermal printer or any RS232 printer.
   Graphics capability: Yes
  OTHER OUTPUT FORMS
   Phone modems: Yes
 PROCESSING AND STORAGE
  STORAGE
   Disk drives: Yes
   CMOS RAM: No
  TRANSPORTABILITY: Moderate - not portable - requires CRT display

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
  MODULARITY: Moderate
  WIDE DISTRIBUTION/REPAIR NETWORKS: High
  ABILITY TO CUSTOMIZE: Excellent
  AVAILABILITY OF DESIRED MODIFICATIONS: Excellent

OTHER COMMENTS

The Apple II is the most widely used computer in rehabilitation. This is in part due to the very flexible design of the computer, especially the 8 easily accessible peripheral slots which are provided.

The Apple II does not have upper/lower case, which is a decided disadvantage in many applications. Low-cost ($50) adaptations are available, however, to provide this.

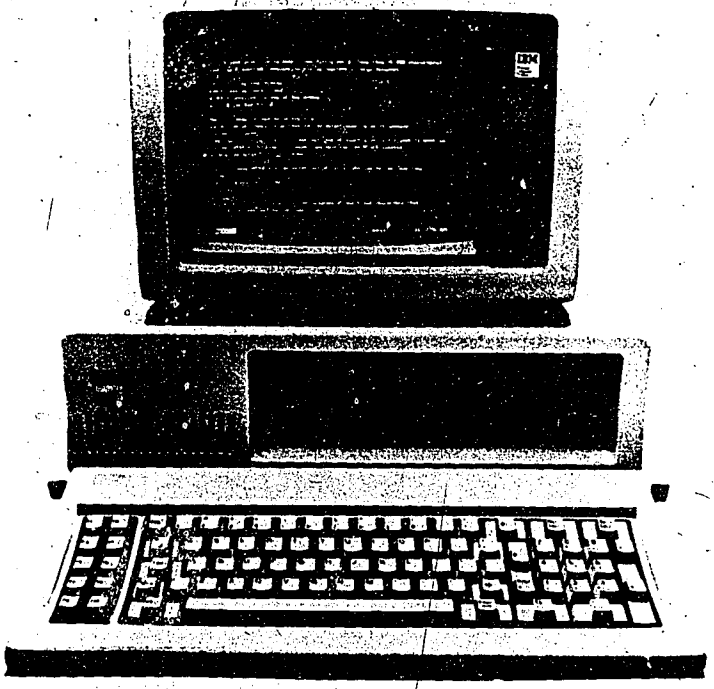


APPLE IIe

OPERATIONAL CHARACTERISTICS
 INPUTS
  KEYBOARDS
   Separable keyboard: No
   Feedback from keys: Standard
   Keyboard size: Standard
   Shift/lock keys: Caps lock key only
   Keyguard availability: Yes -- alternate manufacturer
   Keyboard emulator availability: Yes
  SWITCH INPUTS: 3 provided.
  ANALOG INPUTS: 4 provided.
  LIGHTPEN: Low- and high-resolution lightpens available; alternate manufacturers
 FEEDBACK CHARACTERISTICS
  DISPLAY
   Character size: Moderate in 40-column mode
   Active/Passive lighting display: Active; CRT display
   Upper/lower case capability: Yes
  AUDIO FEEDBACK
   'Click' feedback: Not normally.
   Speech feedback: Will connect to standard RS232 speech output devices.

ABILITY TO MEET NEED
 OUTPUTS
  CORRECTABLE DISPLAYS
   Correctability: Correctable CRT display
   # characters/line: 40/80
   # lines of text on display: 24
   High resolution graphics/color: Graphics; color
  PRINTED OUTPUT
   Printers: Any RS232 printer.
   Graphics capability: Yes
  OTHER OUTPUT FORMS
   Phone modems: Yes
 PROCESSING AND STORAGE
  STORAGE
   Disk drives: Yes
   CMOS RAM: No
  TRANSPORTABILITY: Moderate - not portable - requires CRT display

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
  MODULARITY: Moderate
  WIDE DISTRIBUTION/REPAIR NETWORKS: High
  ABILITY TO CUSTOMIZE: Excellent
  AVAILABILITY OF DESIRED MODIFICATIONS: Excellent



IBM PERSONAL COMPUTER

OPERATIONAL CHARACTERISTICS
- INPUTS
  - KEYBOARDS
    - Separable keyboard: Yes
    - Feedback from keys: Normal keys, but with particularly good tactile feedback
    - Keyboard size: Standard spacing, but large number of keys
    - Shift/lock keys: Capital locks key; shift and control keys must be held down while other key is activated.
    - Keyguard availability:
    - Keyboard emulator availability:
  - SWITCH INPUTS: Yes, with accessory card.
  - ANALOG INPUTS: Yes, with accessory card.
  - LIGHTPEN: Yes, with accessory card.
- FEEDBACK CHARACTERISTICS
  - DISPLAY
    - Character size: Two sizes; moderate and smaller - dependent on TV display and characters/line.
    - Active/Passive lighting display: Active - CRT display
    - Upper/lower case capability: Yes
  - AUDIO FEEDBACK
    - 'Click' feedback: Natural click from key switches.
    - Speech feedback: Will connect to standard RS232 speech output devices.

ABILITY TO MEET NEED
 OUTPUTS
  CORRECTABLE DISPLAYS
   Correctabilities:
   # characters/line: 40 or 80
   # lines of text on display: 25
   High resolution graphics/color: High resolution graphics; color
  PRINTED OUTPUT
   Printers: Any RS232 printer.
   Graphics capability: Yes
  OTHER OUTPUT FORMS
   Phone modems: Yes
 PROCESSING AND STORAGE
  STORAGE
   Disk drives: Yes
   CMOS RAM: No
  TRANSPORTABILITY: Minimal - non-portable CRT display required.

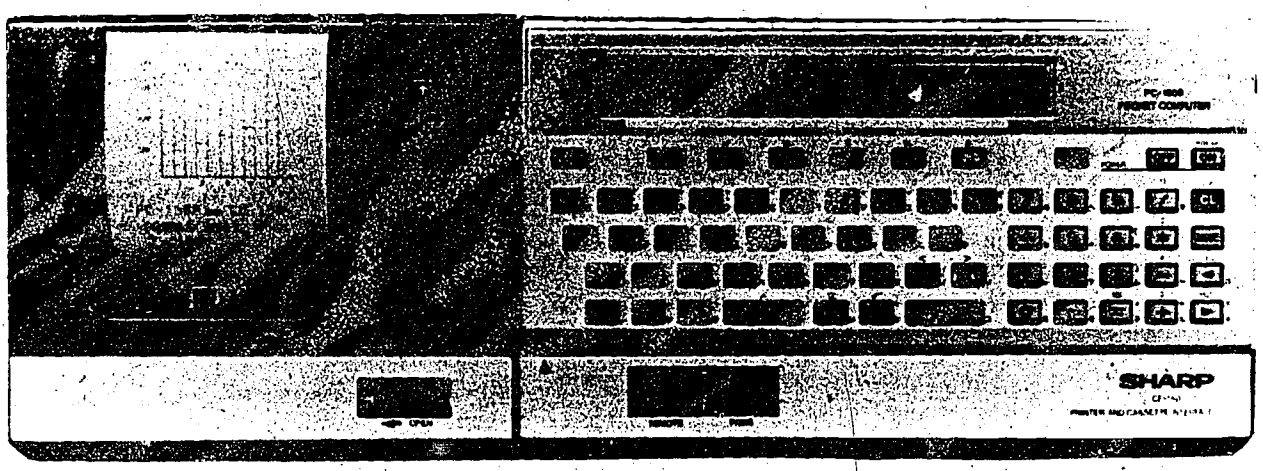
CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
  MODULARITY:
  WIDE DISTRIBUTION/REPAIR NETWORKS: High
  ABILITY TO CUSTOMIZE: Moderate to high
  AVAILABILITY OF DESIRED MODIFICATIONS: Minimal to moderate

OTHER NOTES

Excellent monochrome business display provides clear and highly defined characters. High-resolution graphics and color area also available, but come as a separate board which can be secured along with or instead of the monochrome display.

Again, selection of computers in this category is generally done not to meet the personal needs of the individual, but to meet some business or vocational application. The availability of particular software may be the driving force here.

The IBM PC does have accessory slots designed similar to those of the Apple II. As such, its architecture is highly amenable to special modifications, should a computer with these high capabilities be required.



SHARP 1500/RADIO SHACK PC-2

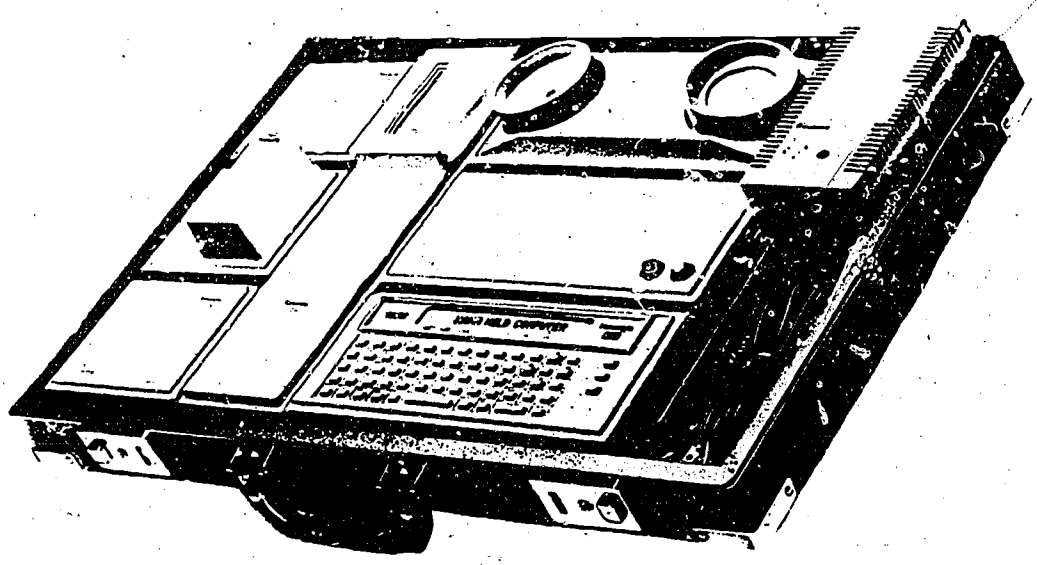
OPERATIONAL CHARACTERISTICS
- INPUTS
  - KEYBOARDS
    - Separable keyboard: Not separable, but entire computer small and repositionable.
    - Feedback from keys: Moderate tactile.
    - Keyboard size: Small
    - Shift/lock keys: Single finger operation supported.
    - Keyguard availability: ---
    - Keyboard emulator availability: ---
  - SWITCH INPUTS: ---
  - ANALOG INPUTS: ---
  - LIGHTPEN: ---
- FEEDBACK CHARACTERISTICS
  - DISPLAY
    - Character size: Moderate to large
    - Active/Passive lighting display: Passive - LCD display
    - Upper/lower case capability: Yes
  - AUDIO FEEDBACK
    - 'Click' feedback: Not normally
    - Speech feedback: Will connect to standard RS232 speech output devices.

ABILITY TO MEET NEED
OUTPUTS
CORRECTABLE DISPLAYS
Correctability: LCD display
characters/line: 20
lines of text on display: 1
High resolution graphics/color: High resolution graphics yes; color no (no TV accessory)
PRINTED OUTPUT
Printers: Ballpoint printer
Paper width: 2"
Graphics capability: Yes
OTHER OUTPUT FORMS
Phone modems: Announced; not available
Other items:
PROCESSING AND STORAGE
STORAGE
Disk drives: No
CMOS RAM: Yes
TRANSPORTABILITY: Excellent - portable - assembles to a single unit

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
MODULARITY: Moderate
WIDE DISTRIBUTION/REPAIR NETWORKS: Good to excellent
ABILITY TO CUSTOMIZE: Minimal
AVAILABILITY OF DESIRED MODIFICATIONS: Minimal

OTHER COMMENTS

No expansion accessories are currently available for this. Therefore, most of the applications will deal strictly with software adaptations of such things as a small portable writing system. The four-color X-Y plotter printer allows very flexible printouts and graphics.



HHC

OPERATIONAL CHARACTERISTICS
- INPUTS
  - KEYBOARDS
    - Separable keyboard: Not separable, but entire computer small and repositionable.
    - Feedback from keys: Moderate tactile.
    - Keyboard size: Small
    - Shift/lock keys: Single finger operation supported.
    - Keyguard availability: ---
    - Keyboard emulator availability: ---
  - SWITCH INPUTS: ---
  - ANALOG INPUTS: ---
  - LIGHTPEN:
- FEEDBACK CHARACTERISTICS
  - DISPLAY
    - Character size: Moderate to large
    - Active/Passive lighting display: Passive - LCD display
    - Upper/lower case capability: Yes
  - AUDIO FEEDBACK
    - 'Click' feedback: Not normally
    - Speech feedback: Will connect to standard RS232 speech output devices.

ABILITY TO MEET NEED
OUTPUTS
CORRECTABLE DISPLAYS
Correctability: LCD display
characters/line: 32
lines of text on display: 1
High resolution graphics/color: High resolution graphics; no color except on accessory CRT controller module

PRINTED OUTPUT
Printers: Thermal, impact, and ballpoint printers available.
Paper width: 2" and 4"
Graphics capability: Yes

OTHER OUTPUT FORMS
Phone modems: Yes

PROCESSING AND STORAGE
STORAGE
Disk drives: Announced; not available
CMOS RAM: Yes

TRANSPORTABILITY: Excellent - portable modular built-in display

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
MODULARITY: Excellent
WIDE DISTRIBUTION/REPAIR NETWORKS:
ABILITY TO CUSTOMIZE: Moderate
AVAILABILITY OF DESIRED MODIFICATIONS: Minimal at this time

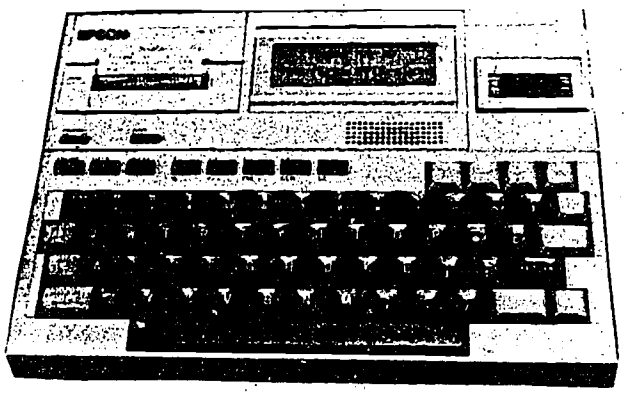
OTHER COMMENTS

High-powered portable hand-held computer. Has an interesting capability of accepting three 16K EPROMs as plug-in modules within the unit.

Although it comes as many small pieces, there is an expansion tray which will hold several of the accessories at one time in a semi-rigid structure. In addition, the structure could be reinforced to have a collection of the unit and sub-units function as a single one-piece unit.

Because many of the capabilities for this computer come as separate modules, be sure to include all of the required modules when pricing this system.

This computer has a FORTH-like SNAP language available for it which allows for compact and efficient programming of the unit.



EPSON HX-20

OPERATIONAL CHARACTERISTICS
 INPUTS
  KEYBOARDS
   Separable keyboard: Not separable, but entire computer small and repositionable
   Feedback from keys: Very close to standard tactile feedback
   Keyboard size: Very close to standard, but not full size
   Shift/lock keys: Shift and control keys must be held down while activating other key (except with special software).
   Keyguard availability: ---
   Keyboard emulator availability: ---
  SWITCH INPUTS: ---
  ANALOG INPUTS: ---
  LIGHTPEN: ---
 FEEDBACK CHARACTERISTICS
  DISPLAY
   Character size: Moderate to large
   Active/Passive lighting display: Passive - LCD display
   Upper/lower case capability: Yes
  AUDIO FEEDBACK
   'Click' feedback: Not normally.
   Speech feedback: Will connect to standard RS232 speech output devices.

ABILITY TO MEET NEED
OUTPUTS
CORRECTABLE DISPLAYS
Correctability: Yes
characters/line: 20
lines of text on display: 4
High resolution graphics/color: High resolution yes; color no (color is available on accessory CRT controller module)

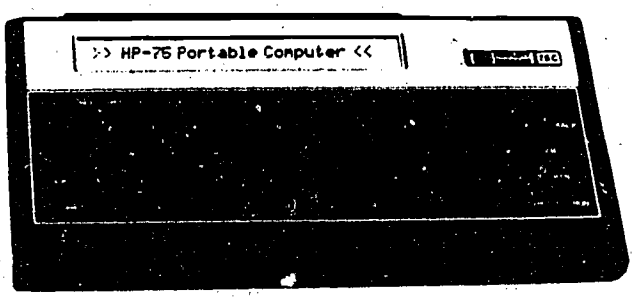
PRINTED OUTPUT
Printers: 20-column impact printer built in.
Paper width: 2"
Graphics capability: Yes
OTHER OUTPUT FORMS
Phone modems: Yes
PROCESSING AND STORAGE
STORAGE
Disk drives: Announced; not available
CMOS RAM: Yes
Computer memory size: 64K (32K ROM)
TRANSPORTABILITY: Excellent - portable - all features built in

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
MODULARITY: Moderate
WIDE DISTRIBUTION/REPAIR NETWORKS:
ABILITY TO CUSTOMIZE: Moderate
AVAILABILITY OF DESIRED MODIFICATIONS: Minimal at this time.

OTHER COMMENTS

Excellent computer for portable writing systems, especially for younger individuals. The unit has one-piece construction which includes a full-size keyboard, a small "mini-screen" display, a printer, and a cassette transport. The 4-line LCD display allows easier visualization of text editing as well as simple math problems. This is extremely important for younger individuals using the system as a writing system for language and math learning. The unit has 2 RS232 serial ports and an optional CRT display to allow it to function as a stationary computer as well.

All of the keys, including the shift and control keys, can be read from a program (using machine language routines), thus allowing one-finger typing programs to be written. (In its normal configuration, however, the system does not allow one-finger typing.)



HP 75

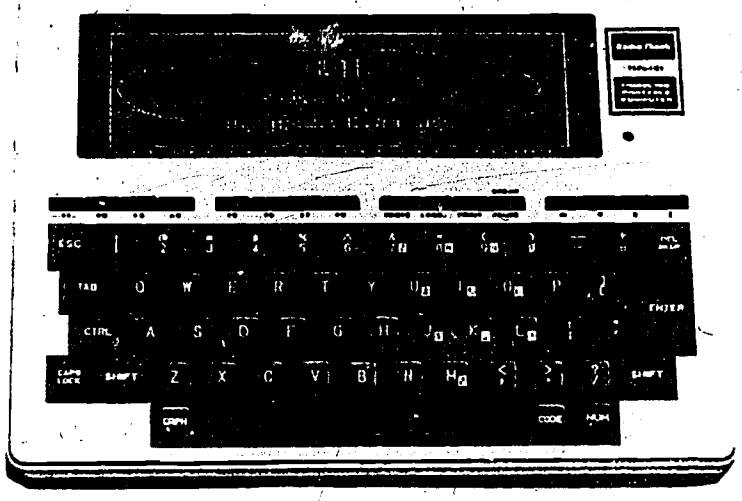
OPERATIONAL CHARACTERISTICS
 INPUTS
  KEYBOARDS
   Separable keyboard: Not separable, but entire computer small and repositionable.
   Feedback from keys:
   Keyboard size: Small, but large enough to pseudo touch-type
   Shift/lock keys: Shift and control keys must be held down while other key is activated.
   Keyguard availability: ---
   Keyboard emulator availability: ---
  SWITCH INPUTS: ---
  ANALOG INPUTS: ---
  LIGHTPEN: ---
 FEEDBACK CHARACTERISTICS
  DISPLAY
   Character size: Moderate to large
   Active/Passive lighting display: Passive - LCD display
   Upper/lower case capability: Yes
  AUDIO FEEDBACK
   'Click' feedback: Not normally
   Speech feedback: Will connect to standard RS232 speech output devices.

ABILITY TO MEET NEED
OUTPUTS
CORRECTABLE DISPLAYS
Correctability: LCD display
characters/line:
lines of text on display: 1
High resolution graphics/color: Available with optional CRT display controller
PRINTED OUTPUT
Printers: Any RS232 printer
OTHER OUTPUT FORMS
Phone modems: Yes
PROCESSING AND STORAGE
STORAGE
Disk drives: Future (built-in card reader now)
CMOS RAM: Yes
TRANSPORTABILITY: Excellent - portable

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
MODULARITY: Excellent
WIDE DISTRIBUTION/REPAIR NETWORKS: Good
ABILITY TO CUSTOMIZE: Moderate
AVAILABILITY OF DESIRED MODIFICATIONS: Minimal

OTHER COMMENTS

High-powered portable CMOS microcomputer. Has an HP-1L bus, making chaning to other accessories simple. Accessories for this are likely to be very expensive, however. In general, this would not be a best buy for use as a portable microcomputer in rehabilitation applications unless specific capabilities of this computer made it ideally suited for specific applications.



TRS-80 MODEL 100

OPERATIONAL CHARACTERISTICS
- INPUTS
  - KEYBOARDS
    - Separable keyboard: No
    - Feedback from keys: Standard keyboard feel; flat keytops
    - Keyboard size: Standard
    - Shift/lock keys: Caps lock only
    - Keyguard availability: No
    - Keyboard emulator availability: No
  - SWITCH INPUTS: No
  - ANALOG INPUTS: No
  - LIGHTPEN: No
- FEEDBACK CHARACTERISTICS
  - DISPLAY
    - Character size: Good
    - Active/Passive lighting display: Passive - LCD display
    - Upper/lower case capability: Yes
  - AUDIO FEEDBACK
    - 'Click' feedback: Not normally, but possible from software
    - Speech feedback: Will connect to standard RS232 speech output devices.

ABILITY TO MEET NEED
OUTPUTS
CORRECTABLE DISPLAYS
Correctability: Excellent
characters/line: 40
lines of text on display: 8
High resolution graphics/color: Graphics; no color
PRINTED OUTPUT
Printers: Any RS232 printer
Graphics capability: Yes
OTHER OUTPUT FORMS
Phone modems: Built-in direct-connect modem. Acoustic coupler optional.
PROCESSING AND STORAGE
STORAGE
Disk drives: Not yet
CMOS RAM: Yes
TRANSPORTABILITY: Excellent

CHARACTERISTICS AFFECTING PURCHASE/MAINTENANCE/ETC.
MODULARITY: 1 piece
WIDE DISTRIBUTION/REPAIR NETWORKS: Excellent
ABILITY TO CUSTOMIZE: Poor
AVAILABILITY OF DESIRED MODIFICATIONS: ---

OTHER COMMENTS

4 pounds; single piece. No printer or mass storage.

NEC has a similar unit being announced. The major difference is that NEC will hold twice the memory (64K of RAM, 64K of ROM) and will have a disk jack on the back of the unit. (Radio Shack may connect a disk to the bus connector of the Model 100).

The unit currently uses alkaline batteries; may announce nicads in the future.

GENERAL GUIDELINES FOR SELECTION OF COMPUTERS

GENERAL GUIDELINES FOR SELECTION OF COMPUTERS

When trying to select a computer for a given application, there are a number of considerations. Actual purchase of the computer is generally the last rather than the first step in this process. The recommended procedure is as follows:

1) Very carefully define exactly what it is that you want the computer to achieve. "I want it to help him with his schoolwork", "I want it to help him write", "I want it to help him communicate", are not sufficient definitions of need. These are general goals or wishes, but not specific functions that you wish the computer to achieve. "I would like the computer to provide him with some mechanism for printing out messages", "I would like it to provide a mechanism for him to write out his homework, making corrections, both at home and at school", or "I would like it to provide my blind son with the ability to write out work and be able to detect and correct his mistakes both at home and at school" are better definitions of needs. In making your description of the needs, use as many paragraphs as necessary, and be as absolutely explicit as possible.

2) When exploring solutions to your problem, look at both computer-based and non-computer-based techniques or approaches to the solution. Also look at technology- and non-technology-based solutions. Often, a simple strategy or technique may be a more powerful and more flexible solution than the electronic or computer-based aid.

3) No computer is of any value without software. The next step should therefore be to identify whether software exists, for any computer, which will provide the functions desired. Carefully examine any software packages available to see whether they provide all of the functions required, or whether they will need modification. Modification to software can be extremely expensive, or impossible, depending upon the complexity of the program, the language it's written in, and the availability of the source code. Writing a program from scratch can be very expensive. A program which could be purchased for $50-$100 may cost $5,000-$20,000 to write. Many of the more expensive programs may have cost $50,000-$100,000 to develop and perfect.

4) Get hold of the software packages (or hardware modifications) and try them out. Many pieces of software sound good when described, but fail to deliver much when actually tried. Also, it is very easy to have over-optimistic expectations of the value of computers in carrying out various tasks. A good demonstration of the software in use can reduce many of these problems, and help to identify truly useful software packages or hardware modifications/ modules.

5) If the software is available for multiple computers, evaluate the various computers to determine which one would be the best for your particular application. The physical characteristics of the computer, its specific features and capabilities, the likelihood that additional software in this area will be developed for each computer, and the availability and maintenance of the computer locally are all factors which should be taken into account.

6) If several computers appear to be equally good, some type of a scoring cross-comparison may be useful. The individual items discussed would be listed, along with a notation as to whether they were absolutely required, highly desirable, desirable, or optional. The various computers can then be compared. Any computer which fails to provide an absolutely required item would be automatically disqualified. Points could then be scored for the other items, and the systems compared against each other in this manner.

7) Check to be sure that the solution is sufficient. Just because you have identified the best of the computer/software packages available does not guarantee that you have a package which is good enough to meet your particular needs or to justify the expenditure. In some cases, it is wiser to wait for additional developments than to move immediately and purchase something which in fact will not meet your needs.

8) Finally, when you have identified a package which is both optimal and sufficient, proceed to purchase all of the components required. When comparing different computers, be sure to compare the entire package price. Often, a computer will look to be less expensive, but its cost will rapidly rise as all of the various accessories and modules are secured to complete the system.

Throughout the process, remember that a little extra legwork on the front end can prove invaluable in the final selection. Also, if you do not see a piece of hardware or software that really meets your needs, do not be afraid to hold off and wait for developments. The field at this time is expanding very, very rapidly. New hardware and new computers are constantly being announced. New programs and special modifications are also being developed in the area of rehabilitation. Check summary documents such as the Proceedings of the Johns Hopkins National Computer Search and the Trace Center International Software/Hardware Registry of Programs Written or Adapted for Handicapped Individuals to see what programs/modifications are available or under development in your area. A short note to some of the principal developers in the area to ask whether they are aware of any new research or aids may also be helpful in identifying new software packages or special hardware adaptations which are still in development stages and not yet documented.

APPENDIX A

COMPUTERS CAN PLAY A DUAL ROLE FOR DISABLED INDIVIDUALS

Computers Can Play a Dual Role for Disabled Individuals

Besides providing special assistance, microcomputers should give disabled individuals access to standard software.

Gregg Vanderheiden, Director
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1500 Highland Ave.
Madison, WI 53706

The move toward more portable and flexible microcomputers is revolutionizing the design and development of electronic assistive devices for the disabled, ensuring the status of powerful, low-cost microcomputers as valuable tools for disabled individuals and those working with them.

The past few years have witnessed a tremendous increase in the number of individuals and small groups involved in the development of special aids for disabled persons. Microcomputers have given individual designers who don't have access to extensive laboratory and production facilities the capability of developing sophisticated electronic aids. This is not to say that the design of aids to assist disabled individuals is easy or can be easily developed in a few weekends or evenings. The worthwhile developments in this area have taken a lot of time and effort, not only in programming and interfacing, but also in carefully studying the real needs of the disabled individuals and the many barriers and practical considerations that are involved in the successful applications of technology to meet their needs.

Worthwhile developments require careful study of disabled individuals' real needs.

The influx of new people into this area has resulted in a wealth of new ideas, energy, and enthusiasm. The purpose of this article is to provide an overview of some of the many areas in which microcomputers can serve the needs of disabled individuals and to discuss a few major concepts important to the development of successful applicable software. I hope this overview will stimulate new ideas, approaches, and applications for microcomputers in those interested in getting involved in designing for the disabled. The basic concepts presented can help you learn from and build upon, rather than duplicate, the early work and mistakes in this area.

A Dual Role for Microcomputers

When we first think about the use of microcomputers by disabled individuals, our minds usually turn to thoughts of text-to-braille translating programs, special communication aids, programs that can teach sign language, etc. These all involve the development of special software that can be run on the computer to provide a specific function required by a disabled individual.

In considering the use of computers by disabled individuals, however, it is very important to remember that disabled people also need to use the same programs and accomplish the same tasks as anyone else. Thus the

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blind individual who may be able to make good use of a text-to-braille program also needs to be able to use standard text editors, spreadsheet programs (e.g., Visicalc), and database managers, to name only a few. Similarly, the physically disabled individuals who could use a game or writing program that requires only the operation of a single switch also need to be able to use the standard educational software as well as the accounting programs and computers at the companies considering them for jobs. This is the dual role that microcomputers must fill: they must help disabled persons perform tasks denied to them because of their disability, and they must be physically modified to allow disabled persons to tap all the microcomputers' computing and word-processing powers.

At present, the vast majority of the software being developed for disabled individuals is limited to providing for a special need, rather than allowing the use of common general-purpose software. These special programs (although often quite sophisticated) are generally easy to implement because the full capabilities of the computer are available to the programmer. They do not, however, address the greater need for disabled individuals to be able to use standard systems.

Trying to provide access to standard software programs for individuals who cannot see the video display or cannot use the keyboard is very difficult. In many cases, the more powerful standard software takes complete control of the computer when it is loaded, disabling the special routines or programs intended to provide access to disabled individuals. This is true even when the special routines are hidden in remote areas of the memory. In addition, the standard programs themselves are often "locked," and the source code is unavailable, making any direct modification of the programs impossible.

Despite the many barriers, strategies are being developed now that can allow extremely motor-impaired individuals to access all standard software, even though the user may have as little controlled movement as an eyeblink.

Providing Special Functions

It would be impossible to quote an exhaustive list of the special functions microcomputers could provide for disabled individuals. Almost any aspect of human activity that has been impaired could potentially be aided to some degree through the use of microcomputers as processors, manipulators, or controllers.

Sensory enhancement/translation: Microcomputers can be used to provide either a clarification of audio or visual information so that it can be more easily understood or a translation from one medium to another. For example, microcomputers can be used to expand visual displays, provide visual displays of auditory information, provide auditory output of visual information, translate a limited, spoken vocabulary into text, and provide tactile displays and feedback to individuals both deaf and blind.

Manipulator/controller: For individuals with severe motor impairments, the use of remote actuators and powered artificial remote prostheses (or robotics) to give them manipulative capabilities has been proposed. One of the difficulties has been the large number of signals that are required in order to control such robots or manipulators. One role for microcomputers might be to help control these remote manipulators by developing and remembering complex movement command strings for specific types of activities. These command strings could then be called upon by the user, using a small number of commands, thus allowing complex motions to be made with reasonable speed and ease.

Information amplification (for motor impaired): The problem of slow information transfer is not restricted to the manipulator/control field. In fact, its greatest impact is probably in the area of communication and writing. Here the speed with which one can transfer information is crucial, and the demand for reasonable speed is extremely high. A difference in speed by a factor of 4 or 5 (the average factor for a motor-impaired individual is around 10 to 20) can make the difference between being able to complete a day's work in a day and taking a week to accomplish a day's work. Similarly, it can be the difference between being able to complete one's homework each night and being able to do one night's homework every week or two. The microcomputer can be used in a number of ways, however, to increase or amplify the amount of information that can be relayed with a given number of keystrokes or signals. Most of these techniques take advantage of redundancy in information transferred, but others are more involved.

A simple example would be an abbreviation expansion routine that would allow an individual to abbreviate all commonly used words and greatly reduce the number of keystrokes required to type out messages, programs, etc. The program would automatically expand the abbreviations as the user typed them. The abbreviations could represent commonly used words, mnemonics, phrases, sentences, or entire blocks of frequently used information.

Another technique would be to use a large word-base that could anticipate the word being typed, thus truncating the process of spelling words out. This can be done based upon word and letter frequency. More elaborate schemes involve looking at idea-to-text or concept-to-text (or even concept-to-speech) translation.

Also being explored is a semantic feature-based phrase/sentence recall system in which three to five keystrokes would define an entire sentence (see "Minspeak" by Bruce Baker, page 186). Only about 60 keys are involved, but their meanings vary as a consequence of the order in which they are pressed. Although this approach at first seems complex, a system like this may be necessary in order to provide the information amplification necessary to offset the severe information-transfer problem that many motion-impaired individuals have. Advances in this field need not be limited to assisting disabled individuals either.

Special control interfaces to other devices: A general method for increasing the information-transfer rate

uses microcomputers to provide a special interface between the disabled individuals and [illegible] device(s) that they are trying [illegible] control. The purpose of this special interface would be to obtain the best possible match between individuals' residual capabilities and the characteristics of the systems that they are using.

Depending upon the severity of the physical handicap, these special interfacing techniques can take a variety of forms. For severely disabled individuals, single-switch input systems can be used; the microcomputer continually presents choices to the user until the user responds by activating a switch.

More common and effective, however, are various special direct-selection or encoding input techniques. For individuals who have head control, screen-based optical headpointing schemes (similar to a long-range light pen) can be used. Other individuals may use expanded and/or recessed keyboards. For those who are able to point but unable to point to a large enough array of elements to represent a full keyboard, smaller arrays consisting of numbers can be used in an encoding fashion to specify the letters, words, etc. Efforts are also currently being directed toward cost-effective methods of using the eyes, both for encoding and for direct selection of items from a display. All of these approaches can be adapted in size and arrangement in order to meet best the needs and capabilities of specific individuals.

A special interface obtains the best match between individuals' residual capabilities and the characteristics of the system they are using.

Recreation and development aids: Disabled individuals can, of course, use microcomputers to play games in the same manner as anyone else. For individuals with severe physical or sensory disabilities, however, microcomputers can play a more extensive role than just recreation. For example, manipulation of objects and exploration of environment important to development in children may not be possible. A specially interfaced microcomputer may be able to offset some of this disability by providing children with a reliable means to control, explore, and manipulate objects either in real space or on a video display. It may also allow individuals to be able to move themselves about in space to gain new perspectives on their environments as well as to reach and act on the objects in it.

Educational aids: In the educational field, a number of specific problem areas can be addressed in part by microcomputers. One area of difficulty involves the slow rate of response of severely physically disabled individuals. This response rate makes any remedial drill or practice session extremely time-consuming (and therefore expensive in terms of personnel time, etc.). Microcomputers can be used to allow individuals to practice lessons independently and at their own speed.

Learning that involves manipulation, such as might be found in chemistry, physics, and other sciences, presents another problem area. Here, microcomputers and computer-aided instruction can allow an individual to manipulate and explore ideas, concepts, figures, etc., in structured but flexible ways. Such programs can allow severely physically disabled individuals to handle "flasks" and "chemicals" on the TV screen and carry out experiments and manipulations that would otherwise be beyond their direct control.

Another whole area for microcomputers in education would be their use not as direct teaching aids but as aids in providing fundamental facilities necessary for a meaningful and effective education. Examples of these aids for a "normal" individual might be eyeglasses or a pencil and paper. The need to see, read and write, take notes, and do independent work are of course necessary capabilities for receiving an education within our current system. The severely physically disabled individual who has no ability to use a pencil and paper, to take notes, to write, or to do independent work is at an extreme disadvantage. Microcomputer-based writing systems designed to provide the same flexibility as a scratch pad and pencil could be used to provide these individuals with the capabilities for appropriate and adequate participation in their educational programs.

Finally, microcomputers can be used to teach fundamental programming skills. Because of the many ways in which microcomputers can aid individuals with disabilities, and because of the direction in which many aspects of the employment world are heading, it is quite clear that microcomputers hold future vocational potential for disabled individuals, whether their vocational direction is in the computer field or not. Computer literacy and the ability to reconfigure or oversee the reconfiguring of computer systems to meet their changing needs may be extremely important capabilities for disabled individuals to have.

Communication aids: Because of the nonportability of microcomputers up to now, their use has been limited mostly to work-station types of applications. These applications include computer-aided writing and filing systems as well as work-station phone control and phone communications using the new speech-output capabilities. However, the stationary systems have not been able to meaningfully address the conversational needs of individuals with severe speech impairments.

The recent introduction, though, of portable and hand-held computers is opening up the potential for microcomputers to move out of the stationary writing-aid category and begin to address the categories of portable writing/note-taking aids and conversational communication aids. Because of the fine motor control required, these portable units will find their greatest initial application for individuals having mild to moderate physical disabilities. When used as components within systems having

other input techniques, however, they may also be used by individuals having more severe disabilities. The limited memory, I/O (input/output), and control capabilities of these systems are currently hampering their application in many areas. In time, the memory capabilities may greatly expand, but the I/O and control capabilities are generally not emphasized in a portable unit and may continue to present problems for awhile.

The major barrier for using microcomputers as communication aids, however, is the need for custom interfacing to achieve optimum speed. This usually involves the development of special interfaces not commercially available. As I will discuss in more detail later, the use of custom hardware in conjunction with standard computers can negate many of the advantages of using a microcomputer in the first place. Care must be taken, therefore, when making a decision between an adapted microcomputer and a specially designed aid to solve problems in this area.

Information resource/management: Disabled individuals could use a microcomputer for information resource/management in all of the same ways that able-bodied individuals can. In addition to these uses, computers can help physically or sensorily disabled individuals to access materials that would normally be difficult for them to handle in a number of ways. Sensory or, particularly, physical disabilities may prevent these persons from making effective use of notebooks, filing systems, calendars, dictionaries, phone lists, etc., due to their inability to quickly manipulate and scan these materials. Microcomputer-based systems with interfaces designed specifically to work with the individual's residual capabilities can provide effective and efficient means of paralleling all of these functions. At present, most of these applications are in the area of *user-generated* information storage and retrieval, although in some cases, such as a dictionary, materials or databases are being developed for general use and dissemination.

Security/monitoring systems: A major barrier to the ability of many disabled or aging persons to live independently is the lack of effective and economical means to ensure their safety and the ability to summon help. Some ways in which a microcomputer could aid in these independent living endeavors would be through the provision of mechanisms for physically disabled individuals to control the locks and windows in their homes, emergency-call systems for individuals who have difficulty in making a call or who are unable to speak, monitoring systems for persons who could fall or in some way render themselves unconscious and unable to call for help, and medication-reminder systems.

A monitoring system could run periodic checks and call for help if the individual does not respond to the system's queries. Reminder systems can be developed both to provide reminders as to when medication should be taken and to check whether certain actions necessary in the taking of the medication (e.g., opening the refrigerator) have been done. Lack of response to these reminders could be used as an alerting signal to the monitoring/call system, which could, in turn, summon aid.

Cognitive and language-processing assistance: Congenital or acquired conditions often leave an individual with impaired cognitive processing. In some cases, it is a general processing deficit, as in mental retardation. In other cases, it is a specific dysfunction of a particular process, such as short-term memory or the ability to program speech or remember names. The greatest obstacle to identifying effective applications of microcomputers in these areas is the limited knowledge about the processes and remediation methods in general. The prospect of microcomputer-based cognitive prostheses is still beyond the current state of the art but not beyond the imagination. The use of microcomputers in remediation, however, may be much closer and more realistic, especially in areas where extensive drill and practice are associated with the remediation process.

Providing Standard Functions

As I stated previously, it is important for disabled individuals to be able to use microcomputers for the same purposes as everyone else does. These purposes include word processing, computer games, computer-aided instruction, control (including environmental control in both the home and job site), financial planning, management, and general computing. In some cases, the disabled individual may use these standard capabilities (e.g., word processing) to help offset specific disabilities (e.g., inability to use a pencil). More and more, however, individuals need to access the standard computer programs because computers are an integral part of their education or jobs. As our society in general incorporates the use of computers into every facet of daily living, access to them is becoming more and more essential.

In order to provide disabled individuals with the ability to run standard software programs, transparent modifications that can circumvent the individual's particular disabilities need to be developed. (The word *transparent* is used here to refer to a technique that is invisible to any standard software programs—that is, modifications cannot be detected by any piece of standard software when this technique is used.) A completely transparent modification does not interfere with the standard program in any way. Similarly, the standard program cannot interfere or negate the modification. A few examples of transparent modifications may be useful here.

The simplest example of a transparent modification is a weight on a hinge that can be tipped to hold down the shift key. This mechanical modification can allow a one-handed or one-fingered (or headstick) typist to enter shift or control characters on the keyboard. There is no way for computers to tell in what manner the individuals are entering data, and any programs will run without modification.

A somewhat more flexible modification may be the use of a keyboard-emulator module, which would be inserted into the computer between the

board-servicing routines. These pure software routines are often loaded from disk into the computer just prior to loading the standard program. In some cases, the routines may be automatically loaded when the computer is turned on. The individual can then use the special routine to select and run other programs.

The major drawback to modifications of this type is that they usually rely on pointers that may often be reset when more sophisticated or complex programs are loaded into the computer. In addition, many of the more advanced programs consume all of the available memory space, totally wiping out such special programs. In some cases, special programs can be hidden in ROM (read-only memory), and special strategies can be incorporated that allow them to continually retake control of the computer even while more complex programs are being run. However, this approach again requires the use of at least some special hardware.

Examples of purely software modifications are the programs written by Peter Maggs at the University of Illinois, Champaign-Urbana (see reference 1) to provide a voice output of video-screen contents (using a variety of speech synthesizers). An example of the ROM-based approach is the adaptive-firmware card developed by Paul Schwejda for the Apple II (see "Adaptive-Firmware Card for the Apple II" by Paul Schwejda and Gregg Vanderheiden, page 276; see also reference 2). In the case of the adaptive-firmware card, the modification is essentially transparent to most programs except those that have critical timing loops around keyboard input routines (the adaptive-firmware card "steals" the microprocessor during these periods).

The SHADOW/VET voice-entry terminal for the Apple (by Scott Instruments) is another example in this category. The SHADOW/VET allows total control of the Apple using voice commands. Except for programs that involve critical timing loops around input routines, the SHADOW/VET can be used instead of the Apple keyboard for all operations even inside protected programs such as Visicalc. (Some keyboard use is necessary during initial voice programming of the unit.)

Multilevel Program Processing and Multitasking

In addition to the transparency problem, designers must understand two other concepts that are important to the development of many microcomputer-based assistive systems, particularly for extremely motor-impaired individuals. The first concept, *multilevel program execution*, refers to the ability of programs to be stacked so that the output of one program serves as the input to the next (for example, a special one-switch input program feeding a communication/spelling acceleration program feeding a standard text editor or other standard program). *Multitasking* refers to the ability to jump back and forth between different programs while keeping all programs active in memory in the computer at the same time (see reference 3).

The need for multilevel program execution stems from practical constraints in the development of programs for disabled individuals. If you had unlimited funds and time, you could develop a single program which contained all of the following:

- input routines (one-switch scanning, Morse code, optical headpointing, etc.)
- acceleration techniques (abbreviation expansion, word/phrase capability, word prediction, etc.)
- function programs (text editing, spreadsheet programs, games, educational programs, etc.)

Similarly, if all of the software were to be written by one group at one university (or company or rehabilitation center), then the software could be written in compatible modules that could simply be linked together to form the configuration desired by a given individual. Because neither of these proposals is practical, especially in light of the extreme variety of programs and functions that would be required on the third level, some type of program nesting is going to be required.

The need for multitasking can best be seen by first imagining an average person sitting at his desk, working on a problem, when the phone rings. He turns and answers the phone. The caller, a colleague, is asking for information for a project she's working on. While on the phone, the person pulls out a file, runs off some calculations, and makes some notes based on feedback from his colleague. He then hangs up and goes back to his writing.

A severely physically disabled individual who uses an assistive microcomputer-based system would need a multitasking capability to accomplish this. First, he would have had to suspend what he was doing (without destroying it or waiting to update and store it) before answering the phone. While on the phone, he would need to access his information system, use his writing system to make notes, and use some computing capability before hanging up the phone and reentering the program he had suspended as the phone rang. During the process, he would need to enter and exit from several programs and routines without losing his place in any of them, thus requiring multitasking.

As with the multilevel program, this problem would not exist if it were possible to write a single, all-encompassing program for each individual. The program could then be written to allow suspension of activity and jumps from one section to another. This approach, however, would not allow the individual to take advantage of any of the standard software constantly being written and updated. It would also deny him access to the programs being used by his peers, as well as programs that may be necessary for him to access as part of his education or employment.

Approaches to the Multilevel and Multitasking Problem

Although current microcomputer operating systems do not allow multilevel and multitasking activities, more sophisticated operating systems are continually being developed. With the increasing memory and processor capabilities of the newer generations of microcomputers, designers can begin to consider the develop-

board-servicing routines. These pure software routines are often loaded from disk into the computer just prior to loading the standard program. In some cases, the routines may be automatically loaded when the computer is turned on. The individual can then use the special routine to select and run other programs.

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The need for multitasking can best be seen by first imagining an average person sitting at his desk, working on a problem, when the phone rings. He turns and answers the phone. The caller, a colleague, is asking for information for a project she's working on. While on the phone, the person pulls out a file, runs off some calculations, and makes some notes based on feedback from his colleague. He then hangs up and goes back to his writing.

A severely physically disabled individual who uses an assistive microcomputer-based system would need a multitasking capability to accomplish this. First, he would have had to suspend what he was doing (without destroying it or waiting to update and store it) before answering the phone. While on the phone, he would need to access his information system, use his writing system to make notes, and use some computing capability before hanging up the phone and reentering the program he had suspended as the phone rang. During the process, he would need to enter and exit from several programs and routines without losing his place in any of them, thus requiring multitasking.

As with the multilevel program, this problem would not exist if it were possible to write a single, all-encompassing program for each individual. The program could then be written to allow suspension of activity and jumps from one section to another. This approach, however, would not allow the individual to take advantage of any of the standard software constantly being written and updated. It would also deny him access to the programs being used by his peers, as well as programs that may be necessary for him to access as part of his education or employment.

Approaches to the Multilevel and Multitasking Problem

Although current microcomputer operating systems do not allow multilevel and multitasking activities, more sophisticated operating systems are continually being developed. With the increasing memory and processor capabilities of the newer generations of microcomputers, designers can begin to consider the develop-

ment of special versions of operating systems specifically designed to allow these types of multilevel and multitasking operation.

If the systems were configured to look like one of the many standard operating systems from the outside, they could in fact run standard programs along with special-function programs. At present, such "super operating systems" do not exist. Moreover, it would take a fairly high-capacity machine to successfully implement such a system. The bulk of the microcomputers being secured and supplied for disabled individuals today are of the much more limited variety. In addition, the software that the disabled individuals must access for their education or employment is also implemented on computers that do not have multilevel and multitasking capabilities. An alternate approach therefore is required that can be implemented now with the existing systems.

A Dual Central Processing Unit Approach

Although a true multilevel, multitasking capability is not currently possible on smaller computer systems, a reasonable approximation of one can be achieved using dual, nested computers. In this configuration, one computer would be used for the input and information acceleration programs as well as some special-function routines. A cable would connect this first computer to the keyboard (or keyboard emulator) on a second computer. The second computer would be used to run the standard software programs (the function-level programs).

Because the first computer would control the second computer through a keyboard emulator, any standard software programs could be run on the second computer without modification. At first glance, using two computers appears to be a brute-force solution; it is, however, the most flexible and straightforward method for dealing with many of the problems—and, in most cases, the *least expensive*.

Because the function-level programs would run on a separate computer, they would not require modification and could be written in any fashion and in any language. Because the entire first computer would be available for these programs, they could be written in a high-level language, thus lowering the cost to develop these special programs. Modifications of these special programs for specific individuals would be much easier, and complex input routines and data structures could be used to optimize the specific user's control and rate of input. This approach would also be much easier to modify and adapt over time to match the individual's changing abilities and needs (see reference 4).

If two identical computers were used in a dual, nested computer approach, the user would have a built-in hardware backup capability. If either computer went down, the other could be put into the input-level position. If the input-program package included some basic-function capabilities, the user would have at least a rudimentary system that could be used during the repair of the faulty computer or component.

It is more likely, however, that the two computers would not be identical. The system is designed so that the two computers do not need to be the same make, brand, model, or size. As a result, the first computer could be implemented on an inexpensive computer selected to provide only the capabilities necessary for the "first-computer" functions. This computer could then drive a much more expensive computer, which would be selected based upon the standard software programs the individual wanted to use.

In fact, the first computer could actually be used to control several different second computers in different environments (an Apple II at home, an IBM at work, and an Atari 400/800 when playing games with friends). In one system being developed at the Trace Center, University of Wisconsin, an Atari computer is being programmed to function as a high speed, screen-based, optical, headpointing input system with abbreviation expansion and dictionary lookup capabilities. The system can then feed a stream of

second computers (including IBM, Apple, and Radio Shack) using keyboard-emulator modules. In one case, the first computer (the Atari 400) costs less than many of the interface cards or accessories for the second computers. No matter which computer is chosen, the software availability for the first computer is not important, because it will be running only the special input routines. It is the second computer that would be selected to match the standard software packages desired by the disabled individual.

Conclusion

Microcomputers are providing existing rehabilitation engineering programs and firms with valuable new tools in the development of specialized communication techniques and aids. They are also opening up the rehabilitation engineering field to an entirely new group of individuals (programmers, etc.) who previously were unable to directly contribute due to the high overhead required in parts and equipment. Whereas work on custom electronic aids usually required that an individual be part of a research team at a center, practical solutions can now be created with little or no hardware components other than the standard microcomputer system and accessories. This is particularly true for special-function programs developed to meet specific needs of disabled individuals.

The problem of providing transparent access to microcomputers (and thus allowing access to the vast world of standard software) usually requires some type of hardware intervention. With the advent of keyboard emulators and the use of dual, nested computers, even this activity promises to be returned soon to the more readily accessed and duplicated world of software. As a result, the immediate future promises to be an extremely exciting and productive period, which will see rapid advances in the development of both special-function programs and new strategies to ensure the complete access by disabled individuals to the world of microcomputers.

If this access can be assured, then the functional disabilities currently

experienced by these individuals should decrease markedly as our society moves more and more into the electronic information age. If we *fail* to ensure access to our computer and information-processing systems for disabled individuals, our progress into the electronic information age will instead only present new barriers.

With good communication among the new group of individuals entering this field, the existing rehabilitation personnel, and most important, the disabled individuals themselves, the amount of truly useful software can be maximized and many existing barriers reduced. It may even be possible to effectively eliminate some disabilities in the same way that eyeglasses have eliminated what would otherwise be a visual handicap for many of us. A possible example of this would be the elimination of the writing handicap currently experienced by many persons with mild to moderate manipulative difficulties (due to a physical disability or severe arthritis) through the development of very effective and portable text-editing systems. Although initially writing speed might be slower, the incorporation of abbreviation expansion and other acceleration techniques would increase speed and give the added benefit of perfect penmanship. ■

References

1. Maggs, Peter and Visek, Dianna. "The Apple Computer as a General Purpose Vocational Aid for Blind Users," *Proceedings, Fourth Annual Conference on Rehabilitation Engineering*, Washington, DC, 1981.
2. *Proceedings, First Annual Computer Search for Handicapped Individuals*, Johns Hopkins University, 1981.
3. Vanderheiden, G. V. "Practical Application of Microcomputers to Aid the Handicapped," *Computer*, January 1981.
4. *Proceedings, Fourth Annual Conference on Rehabilitation Engineering*, Washington, DC, 1981.

Further Reading

The Bulletin of Science and Technology for the Handicapped
American Association for the Advancement of Science
1515 Massachusetts Ave.
Washington, DC 20005

Closing The Gap
(newspaper on computers and the disabled)
Budd Hagen, Editor
Route 2, Box 39
Henderson, MN 56004

Communication Outlook
Artificial Language Laboratory
Michigan State University
East Lansing, MI 48824

COPH Bulletin
Congress on the Physically Handicapped
101 Lincoln Park Blvd.
Rockford, IL 61102

International Software Registry of Programs Written or Adapted for Handicapped Individuals
Trace Research and Development Center
314 Waisman Center
University of Wisconsin
Madison, WI 53706

Link and Go
(includes COPH Bulletin above)
2030 Irving Park Rd.
Chicago, IL 60618

THE ISSUE OF BYTE THAT THIS ARTICLE APPEARED IN ALSO CONTAINS MANY OTHER ARTICLES ON COMPUTERS AND HANDICAPPED INDIVIDUALS.

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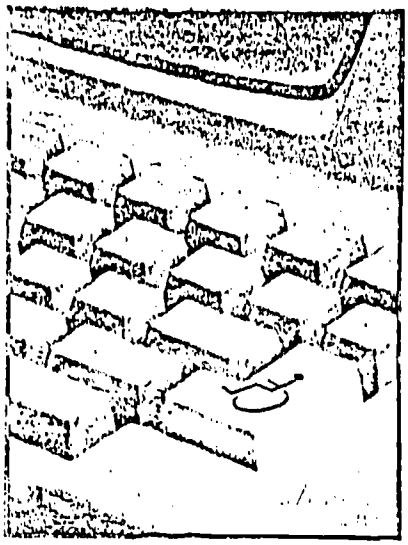

In This Issue

BYTE marks its seventh anniversary with the theme Computers and the Disabled, graphically illustrated on the cover by Robert Tinney. Gregg Vanderheiden discusses how "Computers Can Play a Dual Role for the Disabled," and with coauthor Paul Schwejda demonstrates how to make an "Adaptive Firmware Card for the Apple II." David Stoffel reviews talking terminals for the blind, and William L. Rush evaluates the Abilityphone, a device for nonvocal communication. Patrick Demasco and Richard Foulds show how the Panasonic Hand-Held Computer can be used as a communication device in "A New Horizon for Nonvocal Communication Devices." Steve Ciarcia brings you his latest speech-synthesis system in "Build the Microvox Text-to-Speech Synthesizer: Part 1—The Hardware," and Dr. William Murray reviews The Cognivox VI-1003, a speech-recognition system. Bruce Baker discusses his highly original Minspeak associative memory system for portable speech synthesis, and Alfred Fant Jr. shows you how to use a line printer to produce braille. In case you're thinking of marketing your own computerized aid, see our overview of the FDA's regulations concerning medical devices. In addition to our regular articles and reviews, we have BYTE's Arcade, and we start the countdown on our game contest winners.

BYTE is published monthly by BYTE Publications Inc, 70 Main St, Peterborough NH 03458, phone (603) 924-9281, a wholly-owned subsidiary of McGraw-Hill, Inc. Office hours: Mon-Thur 8:30 AM - 4:30 PM, Friday 8:30 AM - Noon, Eastern Time. Address subscriptions, change of address, USPS Form 3579, and fulfillment questions to BYTE Subscriptions, POB 590, Martinsville NJ 08836. Second class postage paid at Peterborough, N H. 3458 and additional mailing offices. USPS Publication No. 528890 (ISSN 0360-5280). Canadian second class registration number 9321. Subscriptions are $19 for one year, $34 for two years, and $49 for three years in the USA and its possessions. In Canada and Mexico, $21 for one year, $38 for two years, $55 for three years, $43 for one year air delivery to Europe, $35 surface delivery elsewhere. Air delivery to selected areas at additional rates upon request. Single copy price is $2.95 in the USA and its possessions, $3.50 in Canada and Mexico, $4.50 in Europe, and $5.00 elsewhere. Foreign subscriptions and sales should be remitted in United States funds drawn on a US bank. Printed in United States of America.

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BYTE Volume 7, Number 9 September 1982

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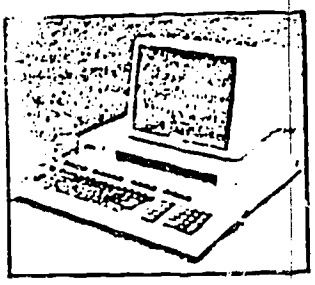

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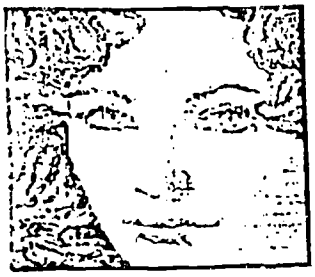

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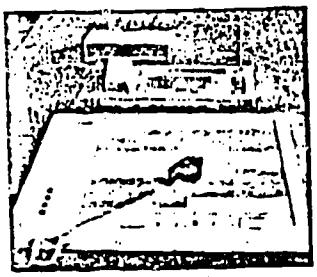

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